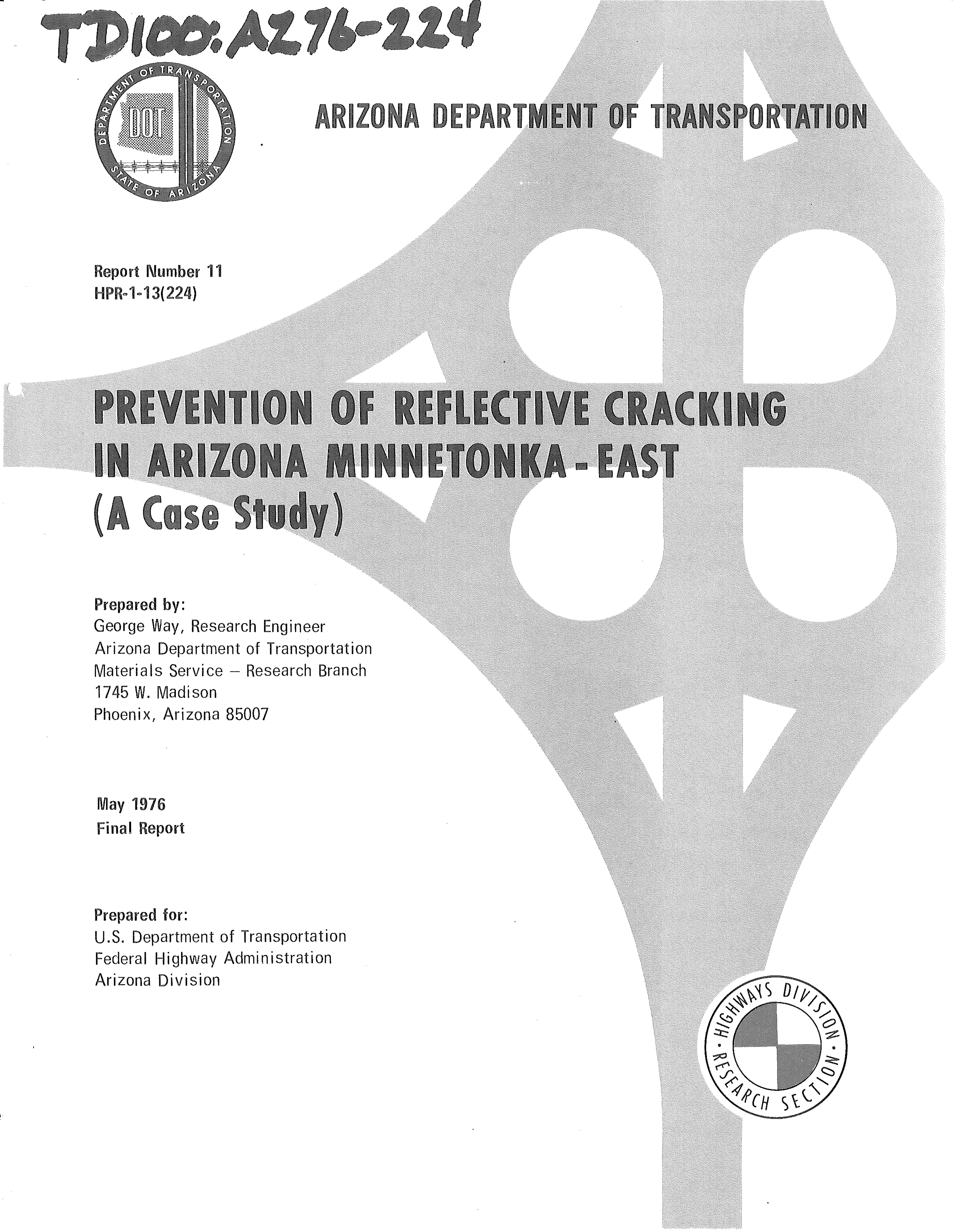

ARIZONA DEPARTMENT OF TRANSPORTATION

Report Number 11
HPR-1-13(224)

PREVENTION OF REFLECTIVE CRACKING IN ARIZONA MINNETONKA - EAST
(A Case Study)

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May 1976
Final Report

Prepared for:
U.S. Department of Transportation
Federal Highway Administration
Arizona Division

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16. Abstract

In conjunction with a thin overlay (1-1/4" AC and 1/2" ACFC) 18 test sections consisting of various treatments were built in 1971 and 1972 to determine to what extent they prevented reflective cracking. From these 18 treatments five were found to significantly reduce reflective cracking. These treatments were:

1. Heater scarification plus petroset
2. Asphalt rubber membrane interlayer
3. Fiberglass
4. Heater scarification plus reclamite
5. 200/300 penetration asphalt

Besides cracking other performance values including roughness, rutting, deflection and asphalt properties are reported, costs in terms of construction and actual maintenance are given. From all of the above each treatments mechanism of failure or success is reviewed and considered in determining the conclusions and recommendations.

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IMPLEMENTATION STATEMENT

The use of asphalt-rubber membrane interlayers and/or heater scarification with rejuvenator agents have been implemented as standard design criteria for all overlays under four inches in thickness where pavement cracking is evident. Heater scarification and rejuvenating agent has been utilized for over four years as a means of revitalizing aged asphalt pavements. In addition, asphalt rubber placed in the form of a seal coat has been used for over three years on badly cracked pavement sections. Fiberglass has not been used and future usage should be on a very limited short section, perhaps maintenance oriented, placement. Lower viscosity asphalt with improved aging characteristics is not currently available to Arizona under the AR grades. Work should be undertaken to communicate this need to industry.

PREVENTION OF REFLECTIVE CRACKING IN ARIZONA MINNETONKA - EAST (A CASE STUDY)

Final Report

Prepared by:
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NOTICE

DEPARTMENT OF TRANSPORTATION STATE OF ARIZONA

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List of Abbreviations and Symbols

AB	Aggregate Base
AC	Asphaltic Concrete
ACFC	Asphaltic Concrete Finishing Course
ADT	Average Daily Traffic
AR	Aged Residue Grading of Asphalt
BTB	Bituminous Treated Base
CS	Control Section
LA	Los Angeles
LL	Liguid Limit
NP	Non-Plastic
PI	Plasticity Index
RTFO	Rolling Thin Film Oven
SM	Select Material
TS	Test Section

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Summary

The primary objective of any pavement design is to provide a roadway of not only safe and desirable ride performance, but to extend these characteristics over a maximum useful life with minimum required maintenance. However, due to the highly complex nature of flexible pavement structures, cracking, rutting and other surface failures do occur and are primarily influenced by environmental, traffic and original design factors. To extend the useful life of deteriorating roadways, generally accepted restoration typically involves the application of a thin asphaltic overlay formulation over the cracked and otherwise deformed pavement.

Historically however, the application of these thin overlays (generally of 4 inches or less) results in a new complex problem, known as "reflective cracking" – defined as the migration of a subsurface cracking pattern into and subsequently through the overlay structure. And of course, once the overlay is fractured, general erosion occurs which severely affects performance and requires further and 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 its occurrence, a case study was conducted by the Arizona Department of Transportation, in conjunction with Federal NEEP Project Number 10 – "Reducing Reflective Cracking in Bituminous Overlays". 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 report describes the Arizona test program – a "case study" involving eighteen selected roadway test sections, with each section serving to evaluate a carefully chosen set of parameters, materials and application methods. The following is a summary of test criteria, results and recommendations.

Preliminary evaluation and program study involved extensive material and treatment research, the selection and evaluation of test site conditions, and the determination of an effective means for data accumulation and reduction. A total of eighteen individual roadway test sections were required and implemented to accommodate the full scope of desired test parameters. Adjacent to each test section was a control section – serving as a normalizing base for comparative measurement. This approach allowed engineers to observe and accumulate qualitative results from each test section, contrast these results, and predict individual parameter influence. From these results, the determination of recommendations based on the effectiveness of crack prevention, cost and other factors were made.

The test program was conducted on a nine mile section of highway (Minnetonka-East), located near Winslow, Arizona on Interstate 40. Winslow is considered a high desert region, with an elevation of 5000 feet and less than eight inches of rainfall annually. Temperature variations range from zero degrees Fahrenheit during the winter to 100 degrees during the summer. Minnetonka-East provided moderate-to-heavy traffic (10,000 ADT), a reasonably severe climate, and a history of severe cracking problems. This section of highway had become eligible for overlay during the year 1967, and was selected for use in the NEEP test program in 1970 – the year the program was initiated.

Preparatory to the test design, extensive pre-evaluation was performed to determine the nature and degree of distress. This evaluation involved many investigations, including core sampling, structural support testing, visual surveys, rut depth measurements, Benkelman Beam tests and traffic surveys.

Federal participation was limited to an overlay thickness of 1-1/4 inches AC and 1/2 inch ACFC. Design engineers considered this thickness to be inadequate to provide the necessary structural support 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 thickness.

The eighteen test sections were unique in design, treatment and materials used. The following table lists a brief descriptive title for each individual treatment by test section number. A more detailed description can be found in Table 5 of the report and in Appendix B.

Test and Control Section Listing

Test Section No.	Description
1	Asphalt Rubber Plus Pre-coated 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	Two Inches AC, No ACFC
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 Of Old AC
18A, B, C	Heater Scarification Of Old AC Plus Reclamite Flush, With Varying AC Overlay Thickness
Control Sections	Conventional (Standard) Overlay

Although various test sections were opened to traffic on an as completed basis, final construction was completed in June, 1972, and exposed to unrestricted traffic. It should be noted that since completion of overlaying in 1972, through 1975 (approximately 3-1/2 years), the highway has been subjected to loads equivalent to the first nine years of original service. That is, Average Daily Traffic (ADT) for 1975 was 10,600, representing 159,213 18-KIP loads, as compared to 3342 ADT for the year 1958, which represents 39,486 18-KIP loads.

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

Since the Minnetonka project was designed to determine what materials and treatments would significantly reduce reflective cracking, it was necessary to accurately determine the extent and type of cracking both before and after overlay. This was accomplished by a special photographic technique and an optical grid system. The number of cracks within each grid element were programmed into a computer for analysis and subsequent time-base comparison. This technique proved very effective. All photo locations were photographed each year through 1975.

Interesting results are provided in the following table – Test Section Ranking. The percentage ranking figures represent a true perspective of percent cracking after overlay. This was accomplished by dividing the percent area cracked after overlay by the percent area cracked before overlay. This test section ranking represents one of the most important parts of this study. It clearly sets forth those five treatments which, when used in conjunction with an ACFC or other suitable open textured surface were capable of significantly reducing reflective cracking. These percentages are particularly significant in consideration of the very thin overlay used.

Generally, rideability is one of the key values in the design of new pavements as well as the rehabilitation of old pavements. Mays-Meter testing was performed both before and after overlay treatment. It was found that those sections constructed without ACFC (T.S. 1 & 6) or blade laid (T.S. 11) demonstrated the poorest performance. Test sections with ACFC over a chip seal (T.S. 3 & 4) or with a higher viscosity asphalt (T.S. 8) performed slightly better. And, test sections using lower viscosity asphalt (T.S. 7, 9 & 10) or matting (T.S. 12 & 13) performed the best.

Also, it was found that basic asphalt properties influenced the reduction of reflective cracking more than any other property. It was found that the 4.0 mega poise at 77°F viscosity (equivalent penetration

Test Section Ranking

Treatment and Test Section (T.S.) Designation		Percent of Reflective Cracking Appearing by 1975
1-¼" AC Overlay and ½" ACFC		
Heater Scarification with Petroset	T.S. No. 2	3
Asphalt Rubber Under ACFC	T.S. No. 3 & 4	4
Fiberglass	T.S. No. 13	5
Heat Scarification with Reclamite	T.S. No. 18 A	6
200/300 penetration	T.S. No. 10	8
Petromat	T.S. No. 12	12
Petroset in cracks	T.S. No. 15	12
Asbestos	T.S. No. 5	13
120/150 penetration LA Basin	T.S. No. 7	14
Emulsion Treated AC	T.S. No. 11	14
Reclamite flush	T.S. No. 17	15
Petroset flush	T.S. No. 14	16
Control sections	——	17
120/150 penetration Four Corners	T.S. No. 9	18
Reclamite in cracks	T.S. No. 16	20
40/50 penetration LA Basin	T.S. No. 8	20
2" AC, No ACFC		
Rubberized asphalt seal coat	T.S. No. 1	19
2" AC no ACFC	T.S. No. 6	64

about 45, absolute unaged viscosity of 3000 poises at 140°F) was critical to crack initiation. That is, the longer an asphalt can maintain a viscosity below 4.0 mega poise, the less likely reflective cracks will occur. Actual physical crack formation and intensity is triggered by cold temperatures. As such, once the asphalt reaches the 4.0 mega poise level, it becomes highly susceptible to cracking. This being the case, it is an important consideration that all system designs use the lowest viscosity asphalt commensurate with strength requirements, and to use it in such a way as to retard aging as much as possible.

The Minnetonka-East program, in conjunction with Federal NEEP Project Number 10, was initiated in an attempt to better understand the mechanism, treatments and methods necessary for the reduction or prevention of reflective cracking in overlays placed over severely cracked bituminous pavements.

This report represents the culmination of over four years of careful planning, construction, and objective data analysis. The results were a myriad of meaningful information which sould be of value to federal, state, and local agencies concerned with not only the restoration of existing roadways, but also new highway construction.

The recommendations contained herein refer to overlays, but in particular, thin overlays (4 inches or less) placed over existing badly cracked, rutted, or otherwise distorted bituminous pavements. Overlaying can also be for reasons of improved skid resistance or rideability, to name a few. The reader should keep in mind, however, that no one treatment is a cure-all for all roadway conditions. Rather, the recommended crack preventing treatments should be integrated into a total overlay design, carefully tailored to the nature of the distress.

Summary Recommendations

Five treatments were found to have significantly reduced reflective cracking.

They are:

- Heater scarification with Petroset
- Asphalt rubber membrane seal coat under ACFC
- Fiberglass membrane
- Heater scarification with reclamite
- 200/300 penetration asphalt

Application considerations are as follows:

- One or more (in combination) of the above treatments should be used for all thin overlays (4 inches or less).
- Heater scarification should always be to a depth of at least 3/4 inches.
- The lowest possible viscosity AC asphalt with the slowest aging characteristics should be used.
- 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.
- Fiberglass membrane material is somewhat cumbersome to use during construction, but could possibly be utilized during maintenance as a pre-overlay treatment on selected small areas.
- Existing roadways which are being considered for overlay should be carefully investigated for possible stripping tendencies. Should stripping appear likely, efforts should be made to either:
  - Give no structural value to the existing AC, or
  - Reconstruct the existing surface
- Open texture surfaces should be placed on top of dense graded overlays. This provides not only good skid resistance, but improves appearance by hiding narrow reflective cracks.

Introduction

Low initial cost, ease of application and highly desirable surface characteristics are but a few of the reasons why asphalt pavements represent the most widely used and accepted form of roadway surfacing. Although preferred and used by most highway agencies, characteristic problems do exist – problems relating to the highly complex nature of asphaltic structures and their susceptibility to cracking, rutting and other failure modes as influenced by environmental, traffic, and original design factors. The primary objective of any pavement design system is to provide a roadway of not only safe and desirable ride performance, but to extend these characteristics over a maximum useful life with minimum required maintenance. However, since cracking, rutting and other surface deformations do occur, generally accepted restoration typically involves the application of a thin asphaltic overlay formulation over the suitably prepared, but cracked pavement.

This method of restoration may subsequently result in a new problem phenomenon – commonly referred to as "reflective cracking". Reflective cracking may be defined as the migration of a sub-surface cracking pattern into and subsequently through the protective overlay. Once the overlay is fractured, general erosion may be quite rapid, thus severely affecting ride and safety performance and requiring the application of further and 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 its occurence, the Arizona Department of Transportation elected to participate in Federal NEEP Project Number 10 – "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 reflected cracks in overlays placed over previously cracked bituminous pavements. Arizona's participation was prompted by poor crack prevention performance in existing and recently applied thin overlay, with a thin overlay being defined as four (4) inches or less in thickness.

The purpose of this report is to describe the Arizona test program – a "case study" involving eighteen selected test sections, with each section serving to evaluate a carefully chosen set of parameters, materials and application methods. Individual test criteria, results and recommendations are presented for consideration by other state and federal agencies in their attempt to better understand and control the reflective cracking problem.

Scope of Work

Arizona's decision to participate in the NEEP Project dictated the development of a planned study and implementation program, involving extensive consultation, treatment and material research, evaluation of test site conditions, and the determination of effective data accumulation and reduction methods. The subsequent study plan called for eighteen individual test sections to fully accommodate all desired parameters. This approach allowed engineers to observe and accumulate qualitative results from each section, contrast these results, and predict individual parameter influence. The results from each test section were compared against each other and also against established control sections – the control sections serving as a normalizing base for measurement. From these results, a myriad of information was obtained, allowing the determination of recommendations based on the effectiveness of crack prevention, cost, and other feasibility considerations.

The Minnetonka-East NEEP Project was initiated and the test site selected in the year 1970. By August, 1971, the program was defined and roadway construction began, with traffic opened as various sections were completed. By June, 1972, all construction was complete and open to traffic. This report includes test results accumulated through December, 1975.

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[1] "Reducing Reflection Cracking in Bituminous Overlays", *National Experimental and Evaluation Program*, FHWA Circular Memorandum No. CMPB–16–70, (May 12, 1970).

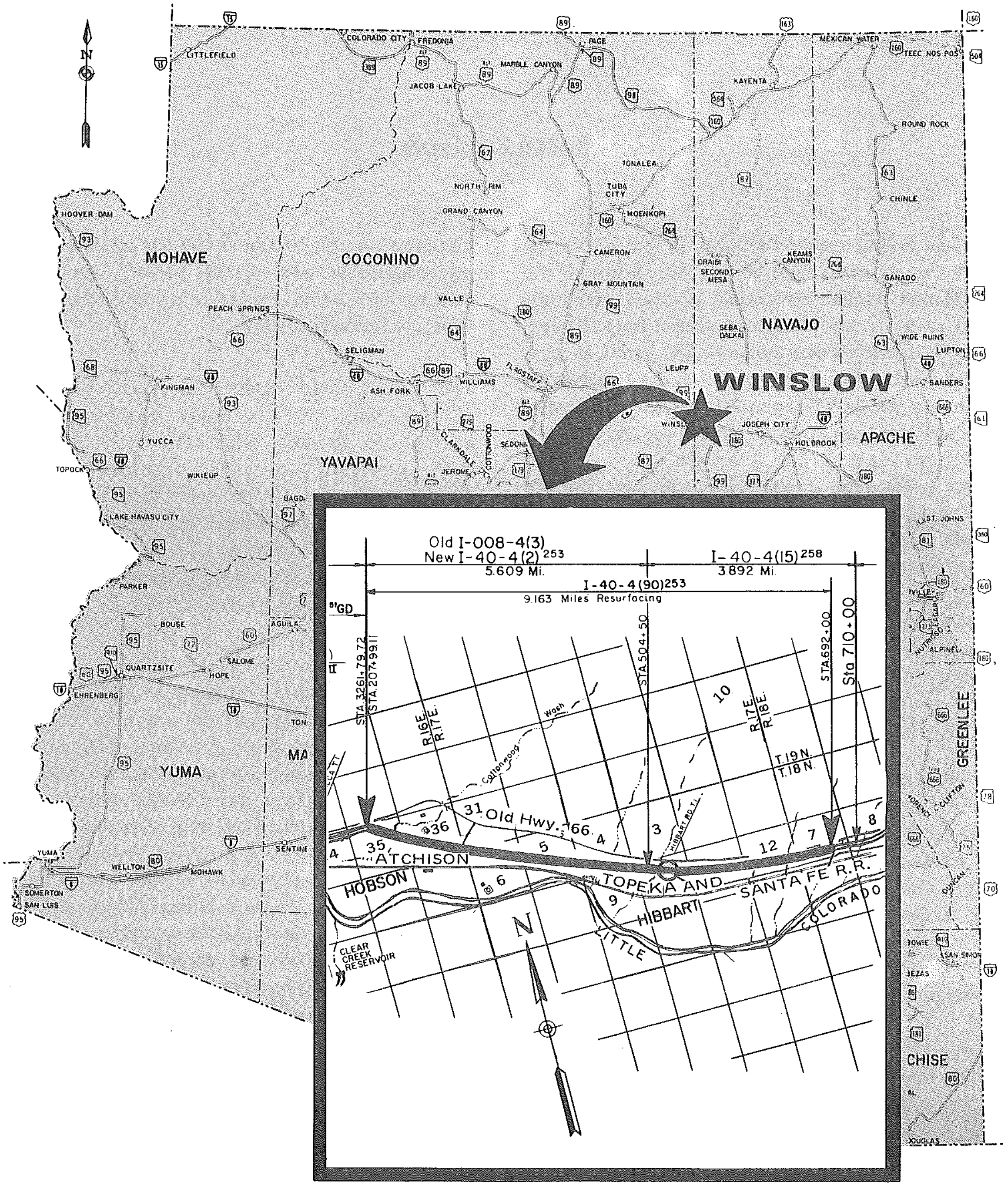

Figure 1. Test Site Location, Minnetonka-East Project I40-4(90) Winslow, Arizona

The Test Program — Minnetonka - East

Test Site Selection

NEEP Project eligibility called for the selection of a severely cracked roadway eligible for overlay during the year 1970 – the year the Arizona NEEP Project was initiated. An overlay project currently under design at that time was Minnetonka-East, located two miles east of Winslow, Arizona on Interstate 40. This overlay project consisted of nine miles of eastbound and westbound highway as shown in Figure 1.

It was in 1967, that this particular highway section became eligible for overlay under FHWA Memo IM 21-1-67 (2). at which time, review by the District Engineer found sufficient distress to warrant an overlay.

Winslow is located in the northeast quarter of the state and is classified as a high desert region, with an elevation of 5,000 feet and less than eight inches of rainfall annually. Temperatures vary from zero degrees Fahrenheit during cold winter days to 100 degrees during the summer. The Minnetonka-East highway was considered a highly desirable test location, providing reasonably severe climatic conditions, moderate-to-heavy (10,000 ADT) traffic loads, and a history of severe cracking problems. Figure 2 shows photographs of representative initial and progressive cracking as observed during the year 1969 – just prior to the NEEP Project.

Minnetonka-East was originally constructed as two projects:

- Interstate 008-4 (3), originally constructed, September, 1958
- Interstate 40-4 (15), originally constructed, August, 1962

As can be seen, the useful life to point of overlay eligibility (1967) for each highway segment was approximately nine years for Interstate 008-4 (3) and five years for Interstate 40-4 (15), with considerable intervening maintenance performed.

A description of original materials and applied thicknesses is presented in Table 1.

Test Program Design

Following FHWA eligibility for overlay in 1967, work began in 1968 to survey the nature and degree of distress, preparatory to determining the overlay thickness required to overcome such problems as rough ride and lack of structural support.

During April, 1969, core samples were taken on 1,000 foot centers to determine characteristics of the base and subgrade materials. Table 1A, Appendix A, provides average index properties of the materials surveyed. Following the material survey, estimated traffic values were computed to satisfy the remaining years of original design life for each highway segment. These traffic values are presented in Table 2.

By July, 1969, the first design memo was completed, indicating required overlay thicknesses varying from 2.50 to 5.75 inches. These thicknesses were considered necessary to provide desired ride and structural support characteristics.

Following this initial design memo, additional investigations were conducted, including visual condition surveys, rut depth measurements, and Benkelman Beam tests. Tables 2A and 3A, Appendix A, show the results of rut depth measurements and the Benkelman Beam test respectively. The results of these tests and observations can be summarized as follows:

	Maximum	Minimum	Average
Rutting (Inches)	1.500	0.000	0.564
Benkleman Beam (Inches)	0.074	0.002	0.035
Condition Survey	Extensive cracking, including block (flexural) and shrinkage (thermal) cracks. Spalling and rutting were also noted.		

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[2] "Additional Stage Construction on Pavement Structures Constructed or Authorized to be Constructed Prior to October, 1963", *1968 Interstate Cost Estimate,* FHWA Circular Memorandum No. IM21–1–67, (May 9, 1967).

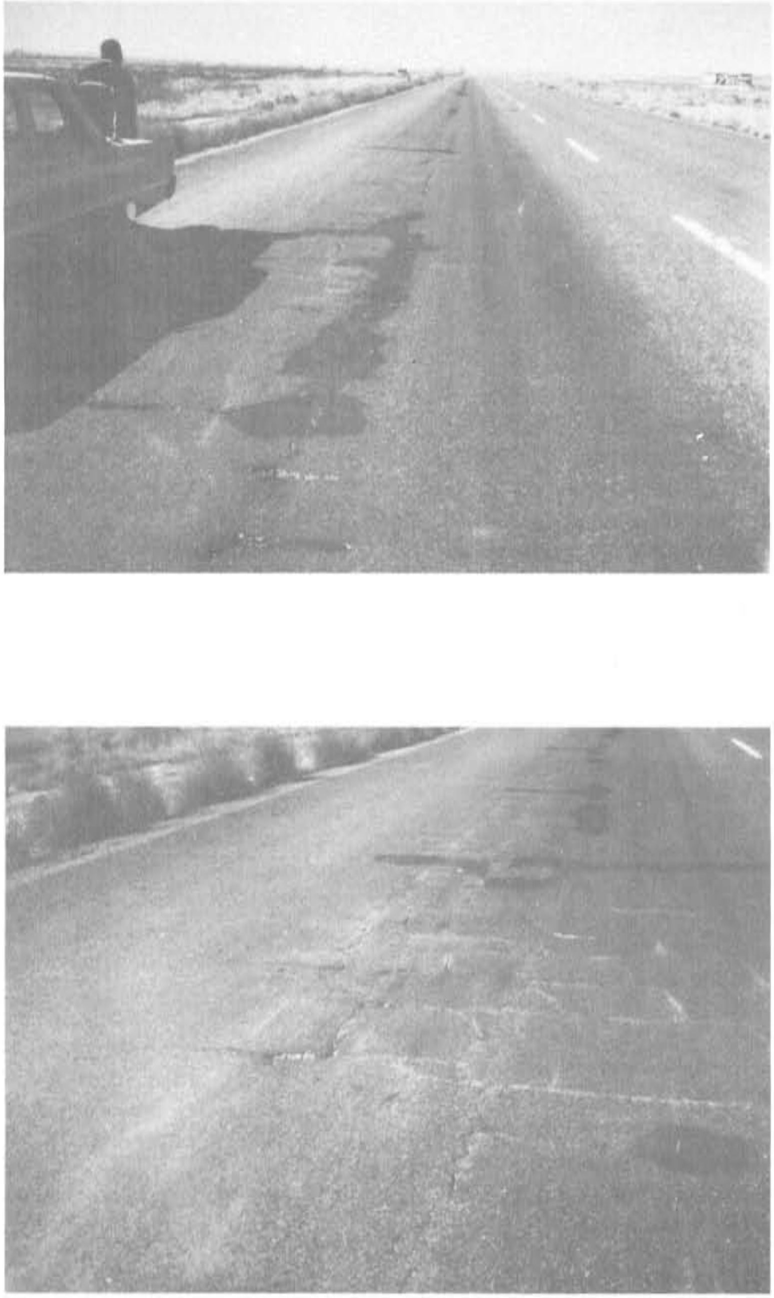

Figure 2. Typical Roadway Cracking, Minnetonka-East,
Photos taken during design phase, February, 1969

TABLE 1
Original Material and Thickness Specifications

Minnetonka - East: Interstate 008-4 (3) and Interstate 40-4 (15)

Interstate	Station	AC	AB	BTB	SM	Sub-Seal	Completion Date
I008-4 (3)	208-504	3.5	–	3.0	6.0 to 15.0	–	1958
I40-4 (15)	504-705	4.0	6.0	–	6.0 to 12.0	9.0	1962

All Thicknesses in inches

Materials Description

Stations 208-504

SM	Select Material: Blow sand.
BTB	Bituminous Treated Base: Blow sand mixed with RC-2 and RC-3.
AC	Asphaltic Concrete: Plant mixed with 200-300 penetration asphalt.

Stations 504-704

Sub-Seal	Subgrade Seal: Blow sand.
SM	Select Material: Blow sand.
AB	Aggregate Base: Terrance sand and gravel deposit (Gravel generally of a chert nature).
AC	Asphaltic Concrete: ¾-inch fine mix. Plant mixed with penetration asphalt.

TABLE 2
Minnetonka-East Traffic Estimates

Interstate 008-4 (3)

Period: 1971 - 1978 to satisfy 7 years design life remaining on I 008-4 (3). Originally constructed: September 12, 1958.

	ADT	Trucks	18 Kip Load (7 Years)
Seven Yr. Est.	8,300	2,042	965,535

Interstate 40-4 (15)

Period: 1971 - 1982 to satisfy 11 years design life remaining on I 40-4 (15). Originally constructed: August 3, 1962.

	ADT	Trucks	18 Kip Load (11 Years)
Eleven Yr. Est.	8,300	2,042	1,670,642

As a result of the above testing and observations, the original design memo of July, 1969, was modified in March, 1971, arriving at a final overlay design thickness. As can be seen from Table 3, the design engineer felt a rather thick total overlay was required to provide the necessary structural support for long term performance. However, for full federal participation, the total overlay thickness was limited to 1-1/4 inches AC plus 1/2 inch ACFC. Where manditory to increase thickness above the federal level, the additional material would have to be placed at the expense of the State (Stations 350-370 & 265-504). In Table 3, the additional AC thickness (labeled future) was not used during this test program due to lack of federal participation.

Designers concluded that the placement of such a thin overlay would produce significant reflective cracking early in the life of the overlay – primarily due to reduced structural support. This early cracking would then warrant extensive maintenance with loss of ride and appearance – in effect – returning the roadway to an unsatisfactory condition in a relatively short period of time. However, this being the case, it was also considered that Minnetonka-East was an ideal choice for a "thin overlay" test program, since valid conclusions would be available within a short period of time. It was on this basis that the test program was to proceed, with, in many cases, rather significant and impressive results.

During development of the NEEP Project study program, extensive consultation, treatment and material research, and careful evaluation of the test site was required, and only after careful consideration of the various materials, construction techniques and treatments (including those specified within the federal NEEP Program) was a parameter matrix determined. From this, selected variations required that a total of 18 different "test sections" be constructed to fully evaluate the more promising design configurations. In addition, it was considered necessary that a "control section" be placed adjacent to each test section. Each control section was treated with a conventional (standard) overlay which served as a normalizing base for measurement. Figure 3 provides a graphic layout of test and control sections for Interstate 40. Generally, test sections were 1,000 feet long by 38 feet wide unless otherwise noted. Control sections were 500 feet long by 38 feet wide.

TABLE 3
Minnetonka-East Final Design Structural Thicknesses
March, 1971

Station	AC Constructed in 1971	Additional AC (Future) Not To Be Constructed in 1971	ACFC	Total (Including Future)
Eastbound				
208-265	1-¼	2	½	3-¾
265-285	1-¼	3-¾	½	5-½
285-295	1-¼	4-¼	0	5-½
295-350	1-¼	3-¾	½	5-½
350-370	2	3	0	5-½
370-504	1-¼	3-¾	½	5-½
405-692±	1-½	2	½	4
Westbound				
208-265	1-¼	2	½	3-¾
265-504	3	2	½	5-½
504-692±	1-½	2	½	4
All Values in Inches				

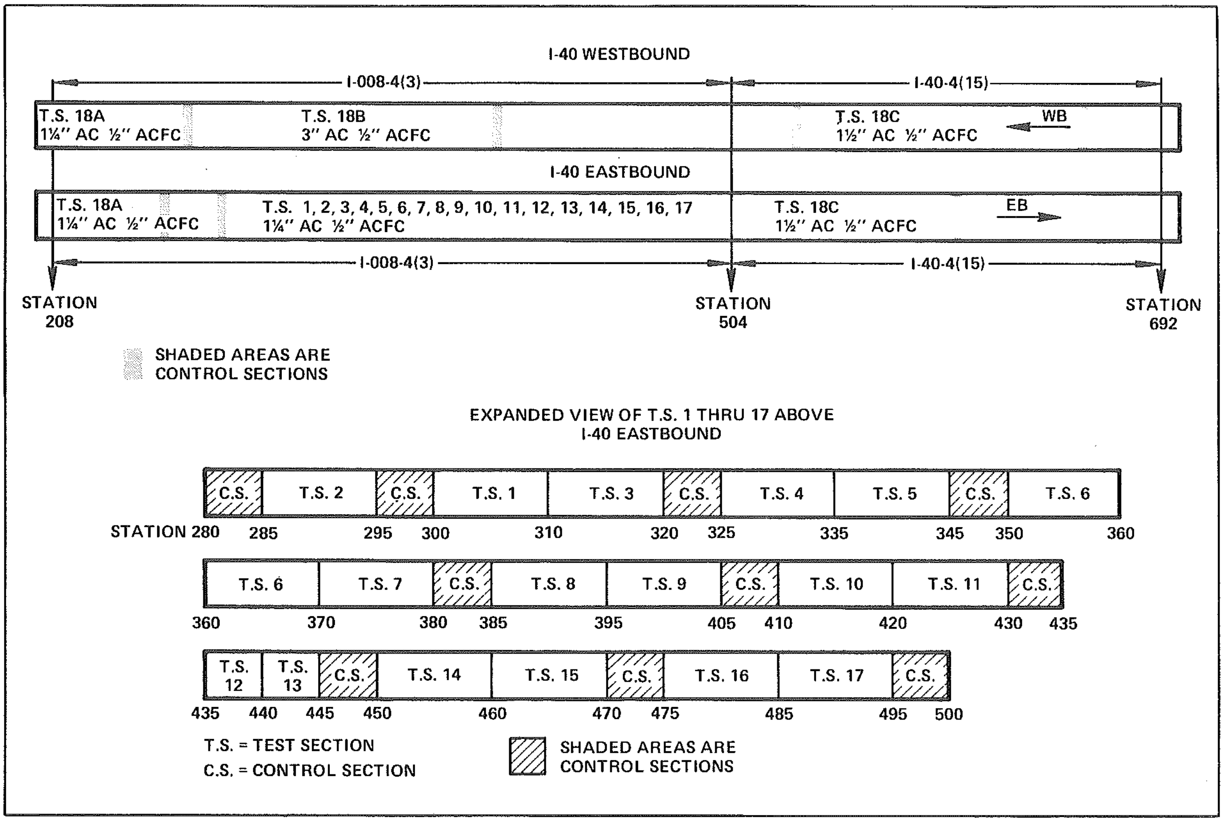

Figure 3. Test and Control Section Layout

Test Section Description

The 18 test sections were unique in design, treatment or materials used. Table 4 provides a quick reference to the individual test sections by descriptive title, while Table 5 provides a more detailed materials and treatment description for each test section and the control sections.

For detailed material and process specifications refer to Appendix B. Appendix B provides design values for AC, ACFC, open graded AC (cold mixed emulsion) and AC with asbestos. In general, the AC was designed to be a 3/4 inch minus dense graded, cinder aggregate, with 10 percent asphalt. The ACFC was a 3/8 inch minus open graded cinder aggregate with 10 percent asphalt. Maximum theoretical denisty (ASTM-D-2041) of the AC was 135.6 pounds per cubic foot.

Test Construction

As is true with many construction projects, highway sections are not necessarily constructed in a sequential, orderly fashion. Instead, the contractor adjusts and tailors his operation to the nature of the work. Since the Minnetonka-East project involved a large number of test sections calling for different treatments, a logical construction sequence was not possible.

To illustrate, Appendix C provides a chronological review of the project construction sequence. Certain construction problems are included since such problems could very well have influenced test performance (3).

Many of the construction problems, however, were peculiar to the nature of a particular treatment and the contractors inexperience in working with certain materials. As an example, specific problems of this type included the "balling" up of fiberglass matting, difficulty in blade-laying the emulsion treated base, the inability of a subcontractor to make a ten percent

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[3] Sisley, B., *Post Construction Report – Minnetonka-East*, Report, Arizona Department of Transportation, District 4, (July 21, 1972).

TABLE 4
Test and Control Section Listing

Test Section No.	Description	Test Section No.	Description
1	Asphalt Rubber Plus Pre-coated Chips	10	Los Angeles Basin 200/300 Penetration Asphalt
2	Heater Scarification Plus Petroset	11	Emulsion Treated Base In Place Of AC
3	Asphalt Rubber Membrane Interlayer - Placed Over AC and Under ACFC	12	Petromat Placed Under Overlay
4	Asphalt Rubber Membrane Interlayer - Placed Over AC and Under ACFC	13	Fiberglass Placed Under Overlay
5	Asbestos Fortified AC Mix	14	Petroset Flush Of Overlay Before ACFC Placed
6	Two Inches AC, No ACFC	15	Petroset Placed In Cracks
7	Los Angeles Basin 120/150 Penetration Asphalt	16	Reclamite Placed In Cracks
8	Los Angeles Basin 40/50 Penetration Asphalt	17	Reclamite Flush Of Old AC
9	Four Corners 120/150 Penetration Asphalt	18A, B, C	Heater Scarification Of Old AC Plus Reclamite Flush, With Varying AC Overlay Thickness
		Control Sections	Conventional (Standard) Overlay

latex emulsion, and construction delays in the distribution of asphalt rubber which caused application of 1.00 gal/yd^2 instead of the intended 0.55 gal/yd^2 on Test Section 1 (See Appendix C).

As it was, prior to and during the construction sequence, Project Engineers spent considerable time consulting with suppliers and other sources to determine what problems might be encountered. As such, although certain problems did occur, they were kept to a minimum. Whether each treatment received equitable consideration during construction can be debated, however, all suppliers and consultants were asked to comment and offer critique during each construction phase; and, generally, no unfavorable comments were reported with respect to the individual treatments.

A few general construction problems did occur which were not peculiar to any particular treatment. These problems were as follows:

1. Compaction – The AC mix used on the eastbound highway, typically, was difficult to compact to the 92 percent minimum compaction specification. Table 6 presents compaction test results for the eastbound and westbound highways. Great effort was placed in overcoming this problem. More compactive force was tried, vibratory rollers were tried, additional asphalt and a more viscous asphalt were all tried, but none of these techniques was able to overcome the fundamental problem. That is, the mix, due to the harsh angular texture of the aggregate (cinders) plus the thickness of the AC mat (1-1/4 inches), made compaction to 92 percent virtually impossible. A change in mix design to blend sand (blow sand), in place of cinder sand, and vibratory rolling did increase compaction for the westbound highway.
2. Rutting – Significant rutting on both highways made placement of 1-1/4 inches AC very difficult. As a result, during April of 1972, considerable additional AC was used as patching material in spalls and ruts of the eastbound highway. In some places the actual depth of pavement placed was closer to 3 inches in the wheelpaths.

Overall, construction of the Minnetonka-East project went quite smoothly, considering the nature and magnitude of the task.

TABLE 5
Test and Control Section Description–Materials and Treatment

1 **Test Section No. 1 - Asphalt Rubber Plus Pre-Coated Chips** a) Tacked old AC with 0.06 gal/yd^2 MC-250. b) Placed 1-¼ inches AC, 85/100 penetration. c) Applied 1.00 gal/yd^2 asphalt rubber; mixture of 25% ground tire rubber plus 75% asphalt (120/150 penetration), plus 5% kerosene diluent by weight. d) Applied pre-coated chips to hot asphalt rubber mixture. e) Rumble rock chip seal placed on distress lane.	**5** **Test Section No. 5 - Asbestos Added To AC Mix** a) Tacked old AC with 0.06 gal/yd^2 MC-250. b) Placed 1-¼ inches AC. Mix modified by addition of 3% asbestos and 3% additional asphalt by weight, 60/70 penetration. c) Placed ½ inch ACFC, 85/100 penetration. d) Rumble rock chip seal placed on distress lane.	**9** **Test Section No. 9 - Four Corners 120/150 Penetration Asphalt** Same as Test Section No. 7, except Four-Corners 120/150 penetration asphalt used.	**13** **Test Section No. 13 - Fiberglass Placed Under Overlay, 500 Foot Test Section** Same as Test Section No. 12, except 0.06 gal/yd^2 MC-250 tack applied to top of fiberglass before AC placement.	**17** **Test Section No. 17 - Reclamite Flush Of Old AC** a) Applied 0.06 gal/yd^2 diluted reclamite flush (dilution; one part water, two parts reclamite). b) Tacked with 0.06 gal/yd^2 MC-250. c) Placed 1-¼ inches AC, 85/100 penetration. d) Placed ½ inch ACFC, 85/100 penetration. e) Rumble rock chip seal placed on distress lane.
2 **Test Section No. 2 - Heater Scarification Plus Petroset** a) Heater scarifying old AC to a depth of ¾ inch. b) Applied 0.10 gal/yd^2 undiluted Petroset. c) Placed 1-¼ inches AC, 85/100 penetration. d) Placed ½ inch ACFC, 85/100 penetration. e) Rumble rock chip seal placed on distress lane.	**6** **Test Section No. 6 - Two Inches AC, No ACFC; 2000 Foot Section** a) Tacked old AC with 0.06 gal/yd^2 MC-250. b) Placed 2 inches AC, 85/100 penetration.	**10** **Test Section No. 10 - Los Angeles Basin 200/300 Penetration Asphalt** Same as Test Section No. 7, except LA 200/300 penetration asphalt used.	**14** **Test Section No. 14 - Petroset Flush Of Overlay Before ACFC Placed** a) Tacked old AC with 0.06 gal/yd^2 MC-250. b) Placed 1-¼ inches AC, 85/100 penetration. c) Applied 0.08 gal/yd^2 diluted Petroset (dilution; one part water, two parts Petroset). d) Placed ½ inch ACFC, 85/100 penetration. e) Rumble rock chip seal placed on distress lane.	**18** **Test Section No. 18A, B, & C - Heater Scarification of Old AC Plus Reclamite Flush** a) Heater scarification to ¾ inch depth. b) Applied 0.10 gal/yd^2 undiluted reclamite. c) Overlay thickness varied; 1-¼ inches (T.S. 18A), 1-½ inches (T.S. 18C) and 3 inches (T.S. 18B). Penetration either 60/70 or 85/100. d) Placed ½ inch ACFC, 85/100 penetration. e) Rumble rock chip seal on distress lane.
3 **Test Section No. 3 - Asphalt Rubber Membrane Interlayer Placed Over AC and Under ACFC** a) Tacked old AC with 0.06 gal/yd^2 MC-250. b) Placed 1-¼ inches AC, 85/100 penetration. c) Applied 0.50 gal/yd^2 rubber asphalt; mixture of 25% ground tire rubber and 120/150 penetration asphalt, plus 5% kerosene diluent by weight. d) Applied cover material chips. e) Placed ½ inch ACFC, 85/100 penetration. f) Rumble rock chip seal placed on distress lane.	**7** **Test Section No. 7 - Los Angeles Basin 120/150 Penetration Asphalt** a) Tacked old AC with 0.06 gal/yd^2 MC-250. b) Placed 1-¼ inches AC, LA 120/150 penetration. c) Placed ½ inch ACFC, 85/100 penetration. d) Rumble rock chip seal placed on distress lane.	**11** **Test Section No. 11 - Emulsion Treated Base In Place of AC** a) Applied 0.10 gal/yd^2 CSS-1h emulsion to old AC, followed by blotter sand. b) Tack coat of 0.06 gal/yd^2 MC-250. c) Placed 1-¼ inches open graded AC made by cold mixing 10% CSS-1h emulsion by weight. d) Applied 0.15 gal/yd^2 CSS-1h emulsion or flush coat. e) Tack coat of 0.06 gal/yd^2 MC-250. f) Placed ½ inch ACFC, 85/100 penetration. g) Rumble rock chip seal placed on distress lane.	**15** **Test Section No. 15 - Petroset In Cracks** a) Filled all cracks with undiluted Petroset. b) Tacked with 0.06 gal/yd^2 MC-250. c) Placed 1-¼ inches AC, 85/100 penetration. d) Placed ½ inch ACFC, 85/100 penetration. e) Rumble rock chip seal placed on distress lane.	**Control Section -** **Control Section - Standard Overlay** a) Tacked with 0.06 gal/yd^2, MC-250. b) Overlay thickness varied; 1-¼ inches, 1-½ inches and 3 inches. Penetration either 60/70 or 85/100. c) Placed ½ inch ACFC, 85/100 penetration. d) Rumble rock chip seal on distress lane.
4 **Test Section No. 4 - Asphalt Rubber Membrane Interlayer Placed Over AC and Under ACFC** Virtually the same as Test Section No. 3. This section not planned. Intended latex emulsion seal could not be made. Excess asphalt rubber from T.S. No. 1 and No. 3 were substituted.	**8** **Test Section No. 8 - Los Angeles Basin 40/50 Penetration Asphalt.** Same as Test Section No. 7, except LA 40/50 penetration asphalt used.	**12** **Test Section No. 12 - Petromat Placed Under Overlay, 500 Foot Test Section** a) Applied 0.23 gal/yd^2 CRS-1h emulsion. b) After emulsion broke, 15-foot width Petromat unrolled onto tack coat. Roll covered travel lane and part of distress lane. c) Placed 1-¼ inches AC on top of Petromat, 85/100 penetration. d) Placed ½ inch ACFC, 85/100 penetration. e) Rumble rock chip seal placed on distress lane.	**16** **Test Section No. 16 - Reclamite In Cracks** a) Filled all cracks with undiluted reclamite. b) Tacked with 0.06 gal/yd^2 MC-250. c) Placed 1-¼ inches AC, 85/100 penetration. d) Placed ½ inch ACFC, 85/100 penetration. e) Rumble rock chip seal placed on distress lane.	

TABLE 6
Average AC Compaction

	% Compaction
Eastbound	
* September 1971	87.2
** March 1975	89.2
Westbound	
* September 1971	91.5

* Represents average of 50 or more tests.
** Computed from 10 cores taken during March, 1975.

Test Environment
After construction was completed in June, 1972, the project was exposed to both unrestricted traffic and varying climatic conditions.

Table 7 shows average daily traffic and 18 KIP loading for the years 1958 through 1975. As can be seen, 18 KIP traffic loading was four times greater in 1975 than in 1958. Since completion of overlaying in 1972, through 1975 (approximately 3-1/2 years), the highway has been subjected to loads equivalent to the first nine years of service.

Climatic variations since overlaying are shown in Figures 4 and 5. Figure 4 indicates average monthly temperature, with the winters of 1971–72 and 1974–75 being the coldest. Figure 5 shows average monthly rainfall, the greatest of which occurred between June, 1972 and March, 1973 – one of the wettest periods on record.

Since cold weather has such a large influence on reflective cracking, a freezing index map was constructed for Arizona. This map, Figure 6, represents values calculated from temperatures reported by 425 weather stations over a 40 year period. Those areas above the zero freezing index line represent regions which normally experience intense cold throughout the winter months. As can be seen from Figure 6, Winslow has a freezing index of 700 – which is quite high.

TABLE 7
Traffic Distribution by Year, Minnetonka-East
1958 through 1975

Year	ADT	Cars	Trucks	18 Kip Loads	Cumulative 18 Kip Loads
1958	3342	2648	668	39,486	39,486
1959	3996	3237	759	46,100	85,586
1960	4621	3743	878	52,230	137,816
1961	5301	4241	1060	58,102	195,918
1962	6039	4771	1268	64,213	260,131
1963	7099	5608	1491	70,436	330,567
1964	7249	5665	1558	76,578	407,145
1965	7395	5817	1552	101,529	508,674
1966	7815	5976	1813	99,949	608,623
1967	7782	5873	1883	111,424	720,047
1968	7979	6110	1843	100,954	821,001
1969	7801	5747	2028	116,267	937,268
1970	8977	6267	2684	129,707	1,066,975
1971	9237	6431	2780	161,372	1,228,347
1972	9701	6694	3007	164,201	1,392,548
1973	10,000	6800	3200	158,123	1,550,671
1974	10,300	6901	3399	160,012	1,710,683
1975	10,600	6996	3604	159,213	1,869,896

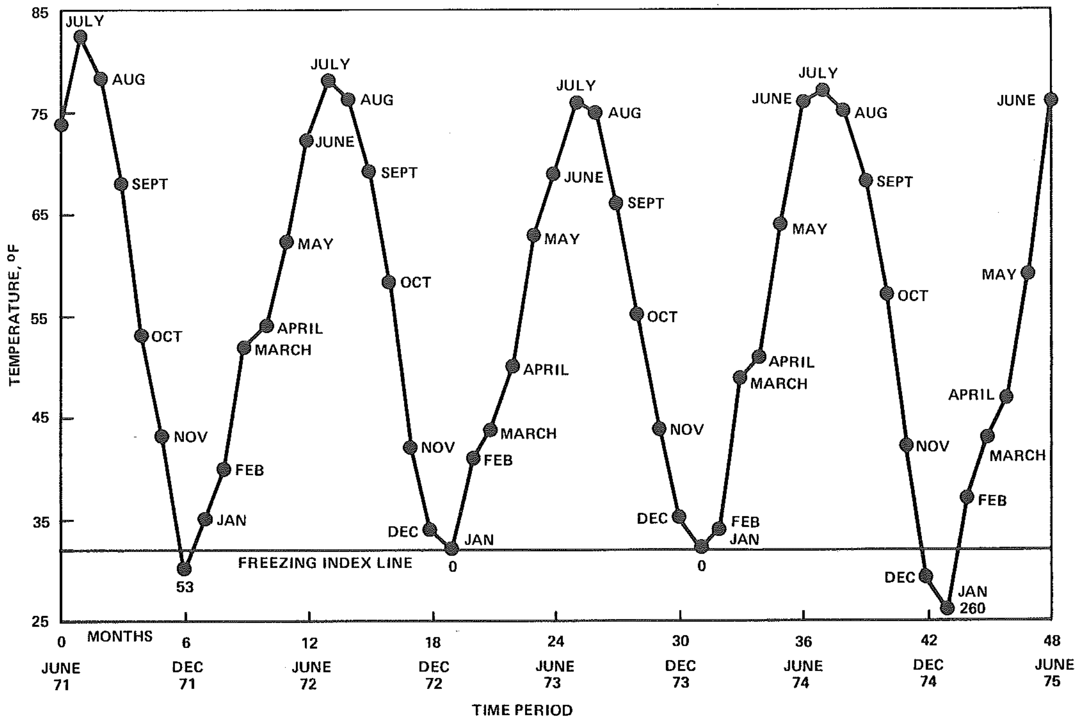

Figure 4. Average Monthly Temperature, Winslow, Arizona

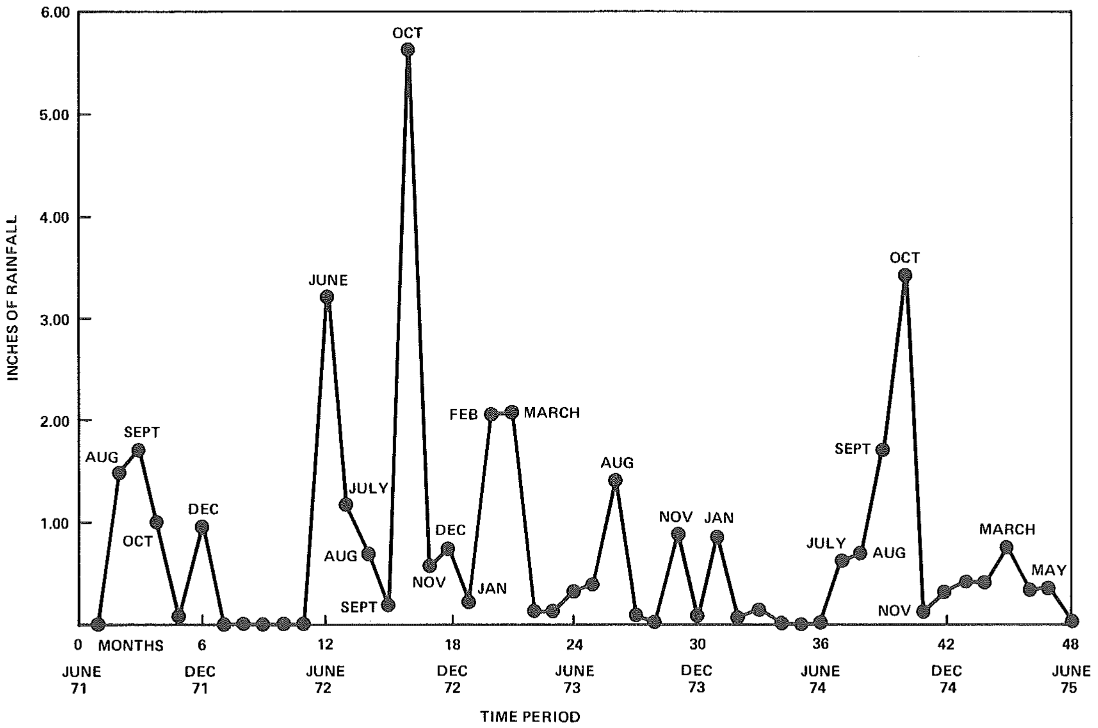

Figure 5. Average Monthly Rainfall, Winslow, Arizona

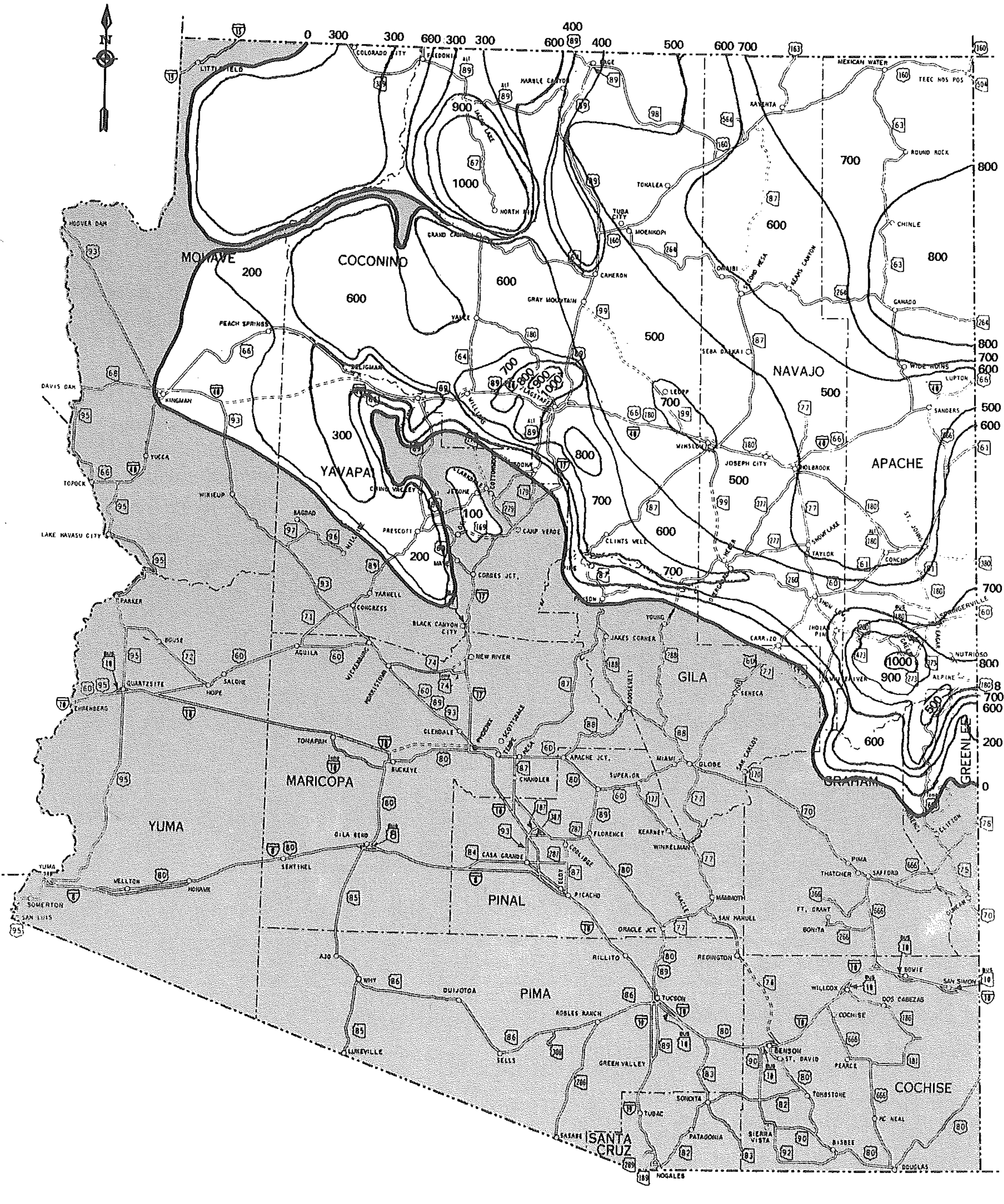

Figure 6. Freezing Index Map, Arizona, Base years 1931–1970 (Based on Monthly Averages)

Test Results

Reflective Cracking Analysis

The Minnetonka project was designed and constructed to determine what materials or treatments would significantly reduce reflective cracking. As such, it was necessary to accurately determine the nature and extent of cracking in the existing highway before the overlay program could begin. Initially, black and white aerial photographs were taken in February of 1971. These photos were scaled one inch to 250 feet and were subsequently enlarged by magnification of 10, to one inch to 25 feet. Unfortunately, these photographs were only able to resolve previously sealed cracks. Unsealed and new reflective cracks could not be seen. Similar aerial photography results were reported by the Maine State Highway Commission (4).

Although aerial photography techniques could possibly have been improved, aerial photo analysis was eliminated from future use for two primary reasons:

1) Future reflective cracks would be less numerous and smaller in size initially.
2) The overlay would be built with a very black aggregate of ten percent or more asphalt, making identification of reflective cracks very difficult.

Since aerial photography was not adequate to visually identify the nature of cracking, an alternate approach was selected. This second approach involved photographing 25 foot highway panel sections from an eleven foot high mobile camera platform (Figure 7), using 35mm color film. Only selected sections were photographed, by selecting the most severely cracked 25 foot area within the travel and distress lanes for each test section.

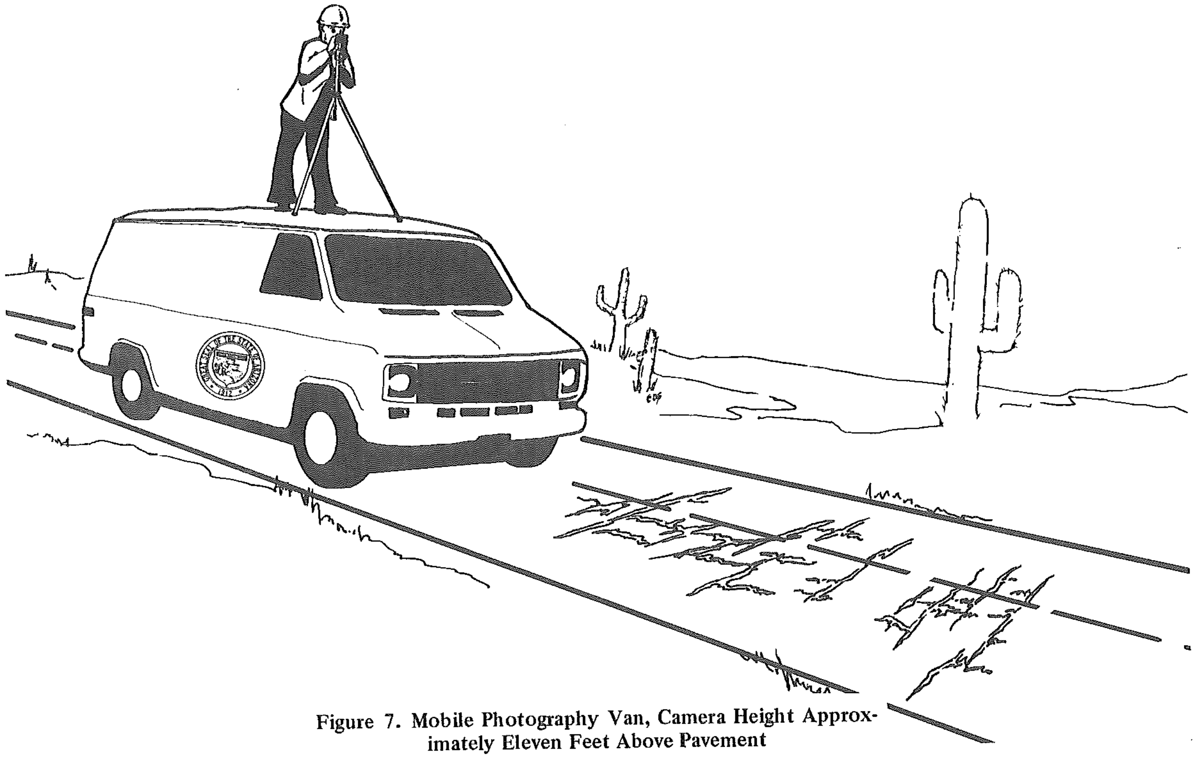

Figure 7. Mobile Photography Van, Camera Height Approximately Eleven Feet Above Pavement

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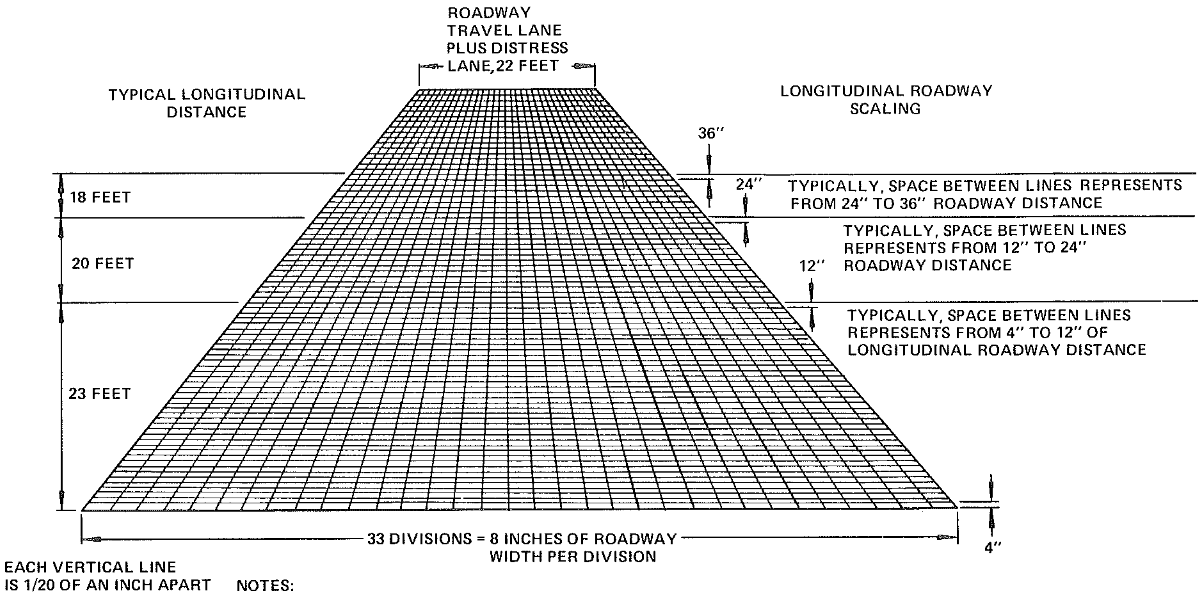
[4] Stoeckeler, E. G., *Use of Color Aerial Photography for Pavement Evaluation Studies,* Maine State Highway Commission, Highway Research Record No. 319, (1970).



NOTES:

(1) SIMILAR TEMPLATES WERE CONSTRUCTED FOR 8" X 10" COLOR PRINTS AND 3" X 5" COLOR PRINTS

(2) NUMBER OF SPACES REVIEWED = 2000 (TYPICALLY)

(3) AREA REPRESENTED ≈ 1410 SQUARE FEET (TYPICALLY)
TYPICAL DIMENSION = 22' X 64'

Figure 8. Template – Crack Count Survey, Glass Template Used, For 5" x 7" Color Print Crack Interpretation (Note 1)

In addition, the highway was divided into 500 foot lengths, and one 25 foot panel per 500 foot length was randomly selected for photographing. A list of all 88 photo locations is provided in Table 4A, Appendix A, with random and worst case locations indicated. These photos were taken in March of 1970.

Photo prints were initially given a cursory examination to guarantee they adequately represented the true cracking condition observed by the author. This examination process subsequently led to the development of a specially made glass template (Figure 8) to aid in the analysis of each color print. This template was designed to compensate for the distortion effect resulting from photographing at an oblique angle. By use of the template, each photo was divided into several thousand discreet parts. Each part was scanned by eye, line-by-line, with each crack occurence being coded onto a computer coding form – indicating exact location. Coded forms were keypunched and processed by a special computer program. This program counted both cracked and uncracked areas and computed the percent area cracked. Figure 9 shows a representative computer printout. The program also put each grid line into proper perspective up to a logical end point. This was accomplished by comparing photos to actual field cracking. From this comparison it was found that distortion did occur with distance. As such, it was necessary to calculate the distance between each grid line, up to a point where loss of clarity took place. Generally this point corresponded to a distance between grid lines of three feet or more. As a result, three feet was incorporated into the computer program as the logical end point at which no further grid lines would be counted for percent cracking calculations.

The above analysis procedure, although initially somewhat cumbersome due to the large percentage of cracked area, proved to be an efficient means of quantitatively determining the magnitude of original cracked area. It was also possible to differentiate to some degree between fatigue or flexural cracking and shrinkage cracking.

During February or March of each year, from 1971 to 1975, each photo location was examined, and those locations showing reflective cracks were again photographed. In 1975 all original photo locations were photographed regardless of cracking. It is impossible to reproduce all photos in this report; however, Figures 10, 11, and 12 are presented as representative examples of photo histories for specific locations. Table 8 presents the percent area cracked for each photo location on a year-by-year basis.

LA 40/50
STATION 386 + 75 – 387 (SEE FIGURE 11, PHOTO 1)

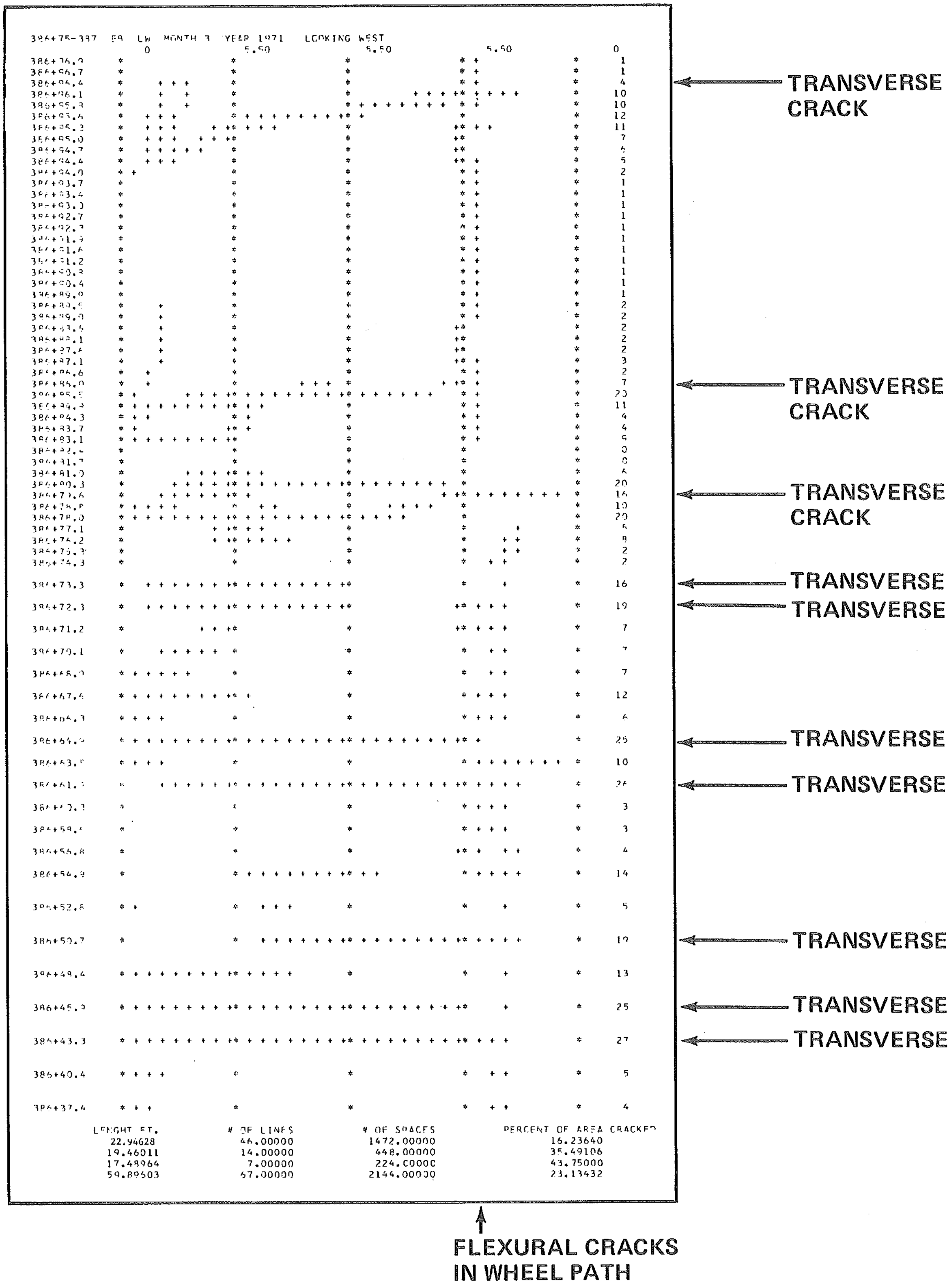
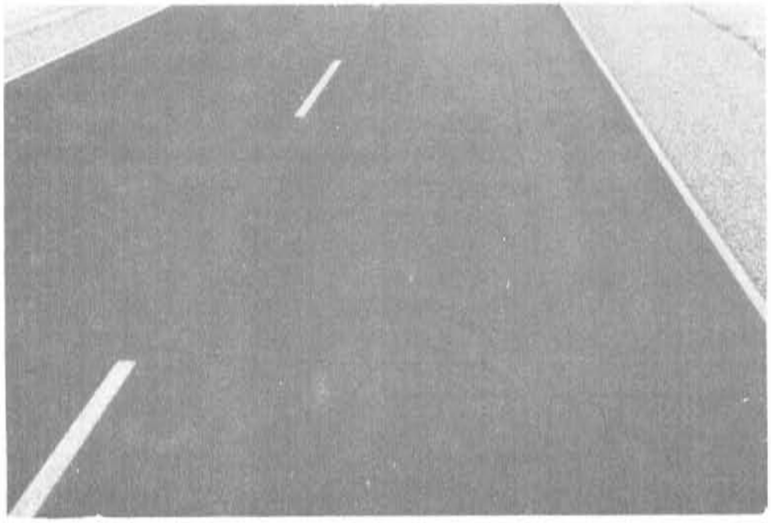

```
384+75-387  E8  LW  MONTH 3  YEAR 1971   LOOKING WEST
```
```
   LENGHT FT.       # OF LINES       # OF SPACES      PERCENT OF AREA CRACKED
    22.94628         46.00000        1472.00000          16.23640
    19.46011         14.00000         448.00000          35.49106
    17.48964          7.00000         224.00000          43.75000
    59.89503         67.00000        2144.00000          23.13432
```

Figure 9. Typical Computer Readout, Crack Survey

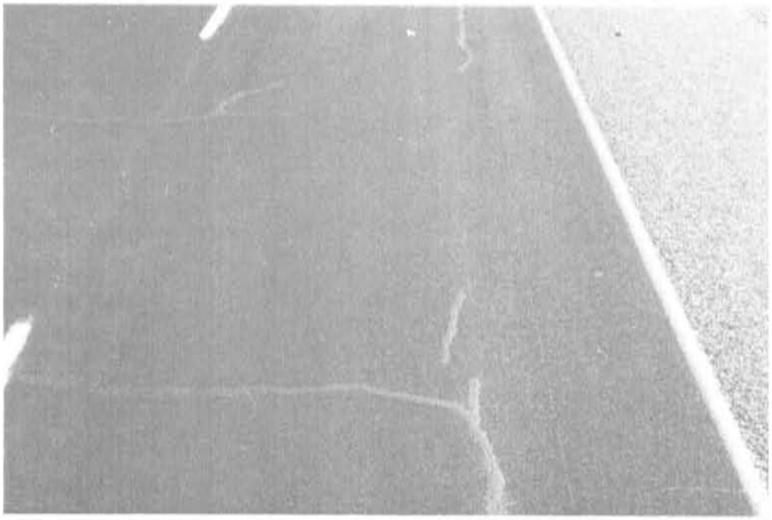
March 25, 1971
23.1% Cracking Before Overlay

March 24, 1972
23.7% Cracking Before Overlay



Feb. 6, 1973
2.9% Cracking or 12.2% Reflected
Cracking After Overlay

Figure 10. Typical History of Cracking, Control Section:
Sta 449+50–75 Eastbound



Feb. 26, 1974
3.6% Cracking or 15.2% Reflected
Cracking After Overlay

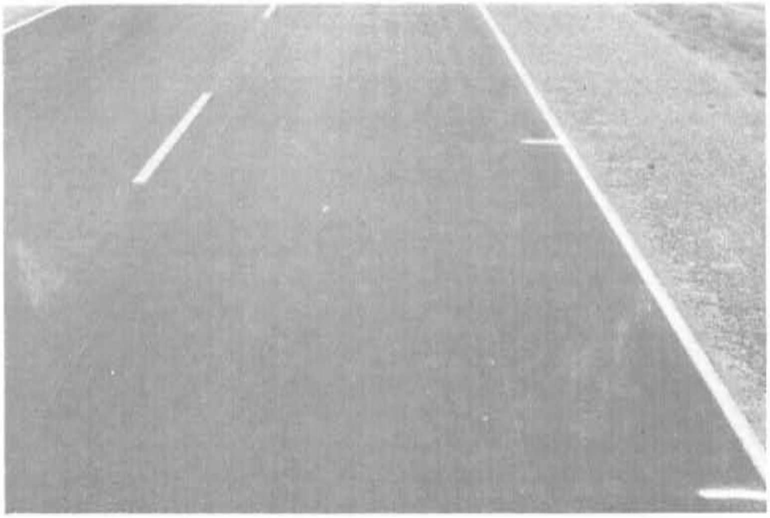
March 13, 1975
8.7% Cracking or 36.7% Reflected
Cracking After Overlay

Figure 10. (Continued)

March 25, 1971, 23.1% Cracking Before Overlay

March 24, 1972
31.1% Cracking Before Overlay

Figure 11. Typical Photo History of Cracking, LA 40/50, Sta 386+75–387



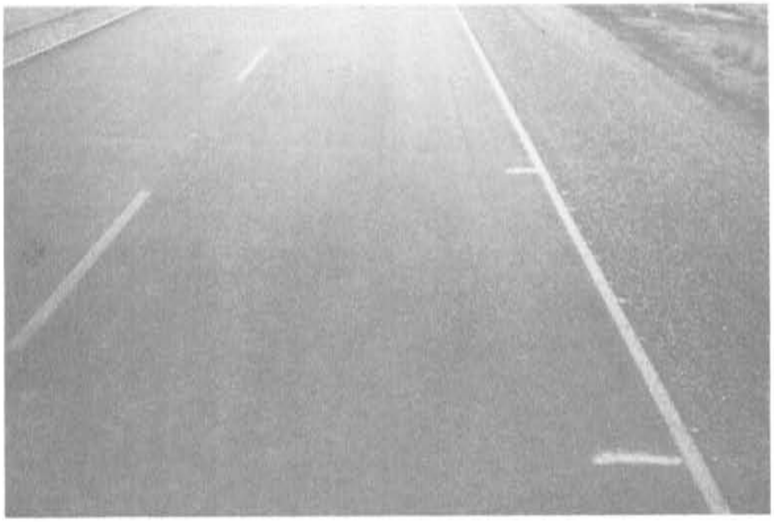
Feb. 6, 1973
.5% Cracking or 1.6% Reflected
Cracking After Overlay

Feb. 26, 1974
2.6% Cracking or 8.4% Reflected
Cracking After Overlay

March 13, 1975
7% Cracking or 22.5% Reflected
Cracking After Overlay

Figure 11. (Continued)

March 25, 1971
13.8% Cracking Before Overlay



Feb. 6, 1973
0% Cracking After Overlay

March 13, 1975
0% Cracking or 0% Reflected
Cracking After Overlay

Figure 12. Typical Photo History of Cracking, Asphalt Rubber Between AC Overlay and ACFC, T.S. #3, Sta 317+75–318

TABLE 8
Percent Reflective Cracking, Minnetonka-East
Cracking Analysis

		% Cracking Before Overlay	% Reflected Cracking* (Base Set 1971)			
Location	Test Section	1971	1972	1973	1974	1975
East Bound						
285+00 - 25	H & S Petroset	1.7	0	0	0	0
292+50 - 75		15.1	0	0	0	7.9
293+50 - 75		12.9	0	0	0	0
229+75 - 230EB	H & S	9.6	0	0	0	0
254+75 - 255EB	Reclamite	7.3	0	0	0	0
266+75 - 267EB	1¼" AC, ½" ACFC	15.0	0	0	0	13.3
239+75 - 240WB		8.1	0	0	0	21.0
588+00 - 25EB	H & S Reclamite	10.2	0	0	0	0
639+75 - 640EB	1½" AC, ½" ACFC	24.0	0	0	0	0
649+75 - 650EB		15.5	0	0	9.0	12.9
599+75 - 600WB		13.0	0	0	3.8	3.8
329+75 - 330WB	H & S Reclamite	7.1	0	0	0	22.5
499+75 - 500WB	3" AC, ½" ACFC	26.3	0	0	0	4.9
EB						
283+25 - 50	Control	11.0	9.1	14.5	7.3	44.5
284+50 - 75	1¼" AC, ½" ACFC	10.8	17.6	19.4	19.4	42.6
295+75 - 296		11.8	15.3	11.9	13.6	32.6
299+75 - 300		11.7	0	0	0	0
498+00 - 25		14.0	0	14.3	35.0	39.3
499+00 - 25		13.0	0	0	0	6.2
499+25 - 50		12.8	0	0	0	3.9
EB						
604+75 - 605	Control 1½" AC, ½" ACFC	16.7	0	0	0	0
WB						
271+75 - 272	Control	8.4	0	14.3	21.4	36.9
401+75 - 402	3" AC, ½" ACFC	13.1	0	0	0	0

$$* \ \% \text{ Reflective Cracking} = \frac{\% \text{ Cracking (Date)}}{\% \text{ Cracking (1971)}} \times 100$$

TABLE 8 (Continued)
Percent Reflective Cracking, Minnetonka-East

		% Cracking Before Over-Lay		% Reflected Cracking (Base Set 1972)		
Location	**Test Section**	**1971**	**1972**	**1973**	**1974**	**1975**
302+75 - 303	Rubberized Asphalt	11.6	16.0	11.9	25.6	26.3
309+25 - 50	seal coat with precoated ships	15.5	21.4	0	0	12.1
310+25 - 5	Rubberized seal	19.1	30.2	0	0	7.9
317+75 - 318	coat under ACFC	13.8	21.8	0	0	0
319+00 - 25		12.2	18.3	0	0	10.4
325+25 - 50	Rubberized seal	14.8	32.0	0	2.5	5.9
326+50 - 75	coat under ACFC	12.6	27.2	0	0	0
334+00 - 25		12.0	11.1	0	0	0
335+00 - 25	Asbestos added	9.4	12.1	0	0	16.5
337+00 - 25	to AC	12.1	32.7	0	0	9.5
341+50 - 75		9.5	10.4	0	0	13.5
353+50 - 75	No ACFC	7.9	8.5	0	11.8	38.8
358+75 - 359	AC 2"	9.8	11.0	0	34.5	90.9
362+50 - 75	Thick	9.5	9.0	0	35.6	118.9
368+00 - 25		19.6	15.6	0	32.7	49.4
368+75 - 369		32.5	31.8	0	17.6	22.3
371+00 - 25	120/150 Pen	30.3	43.5	2.3	4.6	16.3
372+00 - 25	LA Basin	18.2	32.2	0	1.2	12.7
375+00 - 25		28.2	24.5	0	0	13.9
386+75 - 387	40/50 Pen	23.1	31.1	1.6	8.4	22.5
392+50 - 75	LA Basin	42.0	64.1	5.6	25.7	24.6
394+75 - 395		31.7	43.0	0	0	11.9
397+50 - 75	120/150 Pen	28.5	35.0	4.9	21.1	24.9
399+25 - 50	Four Corners	15.2	14.7	0	8.2	19.7
404+00 - 25		12.8	11.7	0	0	10.3

TABLE 8 (Continued)
Percent Reflective Cracking, Minnetonka-East

		% Cracking Before Over-Lay		% Reflected Cracking After OverLay (Base Set 1972)		
Location	Test Section	1971	1972	1973	1974	1975
East Bound						
410+00 - 25	200/300 Pen	25.5	25.7	0	0	10.9
412+74 - 413	LA Basin	24.8	20.3	0	0	2.0
416+00 - 25		12.3	10.0	0	0	10.0
420+50 - 75		25.2	34.1	0	4.7	12.6
421+75 - 422	ETB	19.5	20.0	0	3.0	14.5
426+00 - 25		44.0	46.1	0	0	2.4
427+25 - 50		26.8	34.1	5.9	24.3	28.2
435+00 - 25	Petromat	43.9	44.4	0	0	9.5
437+75 - 438		30.0	32.3	0	0	14.9
440+50 - 75		30.2	29.9	0	0	8.0
440+75 - 441	Fiberglass		30.4	0	1.3	5.3
441+75 - 442			11.1	0	0	0
443+75 - 444			30.5	0	0	5.6
452+00 - 25	Petroset	32.4	31.0	5.8	11.9	20.6
453+50 - 75	Flushed into	44.0	48.9	2.5	8.6	14.3
455+75 - 456	Overlay	32.7	38.1	5.0	7.3	13.4
460+25 - 50	Petroset in	25.2	27.0	0	0	14.1
465+75 - 466	cracks of	37.5	41.5	0	7.0	10.1
467+75 - 468	AC	30.6	40.9	0	2.0	12.5
478+75 - 479	Reclamite	23.2	31.7	0	0	6.3
479+50 - 75	in cracks of	22.2	20.5	8.8	27.3	29.8
483+25 - 50	old AC	15.5	26.1	10.0	16.5	20.3
487+75 - 488	Reclamite Flush	12.8	15.8	0	0	5.7
490+75 - 491	of old AC	16.1	23.7	0	7.6	20.3
491+00 - 25		20.4	17.3	0	0	20.2
320+50 - 75		12.3	25.5	0	0	3.9
322+75 - 323	Control	17.7	25.3	0	0	11.9
346+50 - 75	1¼" AC, ½" ACFC	16.1	34.1	0	0	3.2
349+50 - 75		10.0	19.4	0	0	0
380+75 - 381		35.7	49.2	0	0	5.1
383+25 - 50		40.7	54.2	0	0	6.6
407+75 - 408		26.5	28.5	0	0	6.7
433+75 - 444		18.4	19.0	0	5.3	28.4
448+25 - 50		34.4	39.4	5.6	8.9	12.4
449+50 - 75		23.1	23.7	12.2	15.2	36.7
470+25 - 50		14.3	16.0	0	0	15.6
473+00 - 25		20.0	22.0	0	0	13.6

March 13, 1975
1-1/4" AC With 1/2" ACFC

March 13, 1975
2" AC With No ACFC

Figure 13. Influence of Surface Texture on Cracking, Interface Between Control Section (Containing ACFC and Rumble Rock), and Test Section (Containing No ACFC or Rumble Rock).

As stated earlier, AC paving was delayed due to winter shutdown. From stations 300+00 to 495+00, the old Ac was therefore left uncovered during the winter of 1971–72. Since no maintenance was performed during this period, considerable pavement deterioration occurred. On observing this increased deterioration it became evident that a new "base" set of cracking photos were required. As a result of re-photographing, Table 8 and Table 4A, Appendix A, are divided into two parts. In part one, the March, 1971 photos were used as the base set to determine the percent reflective cracking. For part two, the March, 1972 photos were used – although the March, 1971 values are also listed. This listing of 1971 values shows the amount of distress that can occur over the winter when no maintenance is performed.

As can be seen, each location had different magnitudes of percent area cracked originally as well as after overlay. To put these numbers into true perspective, percent areas cracked after overlaying were divided by the percent area cracked before overlaying to arrive at the *relative percent of reflective cracking.*

$$\text{That Is: } \frac{\%\text{ area cracked (after overlay)}}{\%\text{ area cracked (before overlay)}} = \begin{array}{l}\text{Relative \%}\\ \text{Reflective}\\ \text{Cracking}\end{array}$$

Table 8 shows these values for each location, year-by-year, and further subdivides this data by test section. From Table 8, each test section was *ranked* by percent of reflective cracking. This ranking is indicated in Table 9. Note that Table 9 represents those test sections built with 1-1/4 inches AC and 1/2 inch ACFC, as well as those built with 2 inches AC and no ACFC.

As can be seen from Table 9, It became obvious with time that those sections constructed with and without ACFC performed quite differently. Some might think that ACFC's prevent reflective cracking. This is not true; rather, ACFC's tend to hide reflective cracks. By observing Test Section 6, which used a 2 inch AC overlay with no ACFC, the largest number of cracks were observed. Generally, such cracks were very narrow (less than 1/4 inch). However, an adjacent control section (with ACFC) indicated very little observed cracking. In effect, the open graded ACFC, with its large internal aggregate spacing, could easily hide the equivalent of a hair-line crack structure at the surface, thus hiding narrow cracks in the AC. Similar hiding phenomenon can also be observed on seal coats. If small size aggregate is used, or the seal coat is choked with sand (Test Section No. 1), fine hairline reflected cracks will become evident. This condition was observed in Test Section No. 1. If large aggregate with large spaces are used in a seal coat, cracks become difficult to see. This was evidenced at Minnetonka by the rumble rock seal coat on the distress lane. Again as an example, the interface between the AC overlay with and without ACFC is shown in Figure 13. Note that cracks are discernable in the AC but not where the ACFC or rumble rock have been placed.

The ranking of Table 9, by itself, constitutes one of the most important parts of this study. It clearly sets forth those five treatments, which, when used in conjunction with an ACFC were capable of *significantly reducing reflective cracking.* The importance of these findings are not necessarily the products used, but the principles behind the success or failure of each treatment.

To more clearly understand why and how each treatment performed as it did, additional testing was performed.

Rideability

Generally, rideability is one of the key values in the design of new pavements as well as the rehabilitation of old pavements. PSI, as described in the AASHO Interim Guide (5), is a subjective measure of the smoothness (rideability) of a highway. At Minnetonka, roughness measurements using the Mays-Meter (6, 7) were made before and after overlay treatment. Table 5A, Appendix A, gives inches of roughness for most test sections.

As can be seen, some test sections were not tested prior to overlaying. To overcome this inconsistancy, average roughness values for all reported sections were determined and plotted as shown in Figure 14. The three plotted points, surprisingly, fell close to a straight line; however, this line did not pass through the origin. This indicates that as the length of Mays-Meter test doubled or quadrupled roughness did not double or quadruple. This error is probably the result of interpolating the tape output from a mile length down to 500 foot sections. Table 6A, Appendix A, shows the percent of original roughness computed for all reported tests as well as by test section. In addition, Table 10 shows how each section would be ranked with respect to the various treatments.

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[5] *AASHO Interim Guide for Design of Pavement Structures,* (1972).

[6] Allen, G. J., "Pavement Evaluation In Arizona", *Proceedings of the Eleventh Paving Conference,* University of New Mexico, (January, 1974).

[7] Walker, R. S., and W. R. Hudson, *A Correlation Study of the Mays Road Meter with the Surface Dynamics Profilometer,* Center for Highway Research, University of Texas at Austin, Research Report No. 156-1, (February, 1973).

TABLE 9
Test Section Ranking, 1-1/4" AC Overlay and 1/2" ACFC

Treatment and Test Section (T.S.) Designation		Percent of Reflective Cracking Appearing by 1975
1-¼" AC Overlay and ½" ACFC		
Heater Scarification with Petroset	T.S. No. 2	3
Asphalt Rubber Under ACFC	T.S. No. 3 & 4	4
Fiberglass	T.S. No. 13	5
Heat Scarification with Reclamite	T.S. No. 18 A	6
200/300 penetration	T.S. No. 10	8
Petromat	T.S. No. 12	12
Petroset in cracks	T.S. No. 15	12
Asbestos	T.S. No. 5	13
120/150 penetration LA Basin	T.S. No. 7	14
Emulsion Treated AC	T.S. No. 11	14
Reclamite flush	T.S. No. 17	15
Petroset flush	T.S. No. 14	16
Control sections	———	17
120/150 penetration Four Corners	T.S. No. 9	18
Reclamite in cracks	T.S. No. 16	20
40/50 penetration LA Basin	T.S. No. 8	20
2" AC, No ACFC		
Rubberized asphalt seal coat	T.S. No. 1	19
2" AC no ACFC	T.S. No. 6	64

TABLE 10
Roughness Ranking, Ranked by Percent of Original Roughness, (Eastbound), May 21, 1975

Description	Test Section No.	Percent Of Original Roughness
200/300 Pen.	10	21
Petromat	12	26
Fiberglass	13	43
Reclamite Flush	17	45
120/150 Pen L.A.	7	48
120/150 Pen 4 Corners	9	50
Petroset in Cracks	15	50
Control Section	All Eastbound	57
Petroset Flush	14	59
Heater Scarified & Petroset	2	61
Asbestos	5	62
Reclamite in Cracks	16	65
ACFC over Rubberized	3	85
40/50 Pen	8	85
ACFC over Rubberized	4	91
No ACFC	6	91
Emulsion Treated Base	11	99
Rubberized Seal Coat	1	107

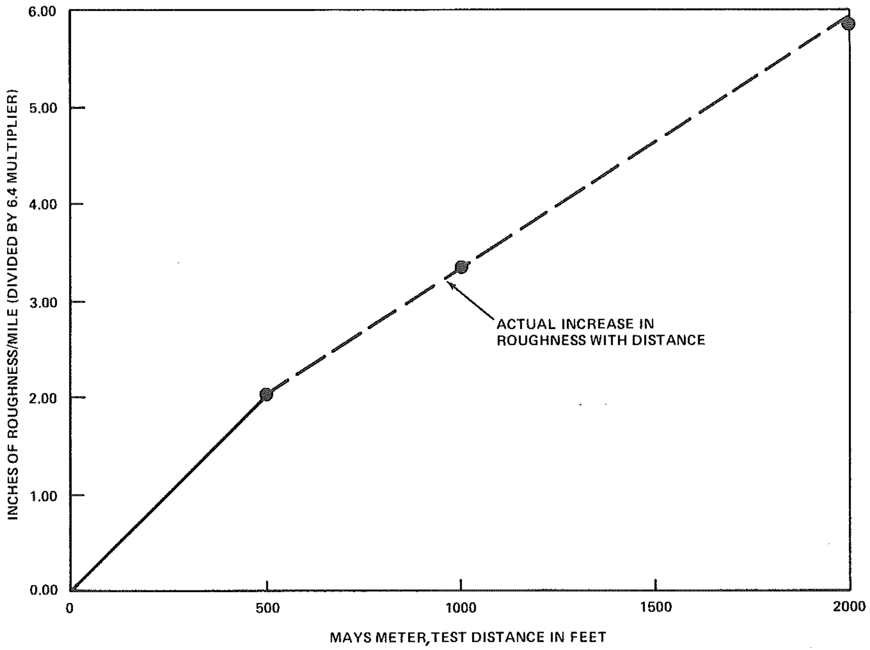

Figure 14, Mays Meter Roughness Before Overlay, (As a Function of Distance)

Table 11 provides a ride index ranking for the various test sections and closely resembles Table 10. Serviceabilities as shown in Table 11, generally have not decreased to the terminal 2.5 index level. However, it should be noted that the original condition of the road was not quite 2.5.

Rideability performance of the overlay generally appeared to be related to the design (8) and construction of the test sections. Those sections constructed without ACFC (T.S. 6, 1) or blade laid (T.S. 11) demonstrated the poorest performance. Test sections with ACFC over a chip seal (T.S. 3 & 4) or with a higher viscosity asphalt (T.S. 8) performed slightly better. And, test sections using lower viscosity asphalt (T.S. 7, 9, & 10) or matting (T.S. 12, 13) performed the best. For low viscosity asphalt, this was probably due to ironing out of paver joints under traffic. The superior performance of the petromat and fiberglass sections must be considered a function of the matting itself; that is, matting apparently restricts vertical movement by a considerable amount. Additional comments on rideability will be discussed in the analysis section.

Rutting

Another meaningful measure of a highways performance is rut depth. Historically, considerable emphasis has been placed on the influence of rut depth on performance. (9) Table 12 shows rut depths of various test sections before overlay in 1970 and on test completion in 1975. Depths recorded in 1975 are not considered excessive. It is interesting to note that the asphalt rubber seal coat (Test Section No. 1) recorded the deepest rut depth. This could possibly be due to unintended over-application of 1.00 gal. per square yard asphalt rubber, which was subsequently deformed under traffic. Other asphalt rubber sections, which received the designed application rate of 0.55 gal. per square yard, demonstrated about one-half the rutting.

Deflection

As stated earlier, the Benkelman Beam was used to determine roadway deflection. Arizona has also been performing dynaflect (10) deflection, before and after overlaying, on a scheduled basis. A recapitulation of all tests is shown below:

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[8] *Pavement Riding Quality,* New Jersey Department of Transportation, Final Report No. 74–001–7713, (April, 1974).

[9] Finn and Nair, *Development of Pavement Structural Subsystems,* Material Research and Development Report No. NCHRP–1–10B.

[10] Allen, G. J., "Pavement Evaluation In Arizona", *Proceedings of the Eleventh Paving Conference,* University of New Mexico, (January, 1974).

TABLE 11
Ride Index Ranking, Serviceability Index

Test Section	Roughness Inches/Mile		Rating After Overlay	
	4/11/72*	5/21/75	Texas S.I.**	Arizona R.I.***
T.S. 10 200/300 Pen	94.6	19.6	4.72	3.99
T.S. 12 Petromat	148.7	39.2	4.40	3.86
T.S. 7 120/150 Pen LA	101.4	44.6	4.32	3.82
T.S. 9 120/150 Pen 4 C.	106.4	53.1	4.16	3.77
T.S. 2 Scarification	111.5	61.5	4.00	3.71
T.S. 5 Asbestos	99.7	61.5	4.00	3.71
T.S. 13 Fiberglass	141.9	61.5	4.00	3.71
T.S. 17 Reclamite Flush	136.9	61.5	4.00	3.71
T.S. 16 Reclamite in Cracks	103.1	66.9	3.96	3.68
T.S. 15 Petroset in Cracks	135.2	67.6	3.94	3.67
Control Section	138.5	68.6	3.72	3.60
T.S. 14 Petroset Flush	136.9	80.8	3.64	3.58
T.S. 13 ACFC over rubberized	111.5	86.5	3.56	3.55
T.S. 8 40/50 Pen.	101.4	86.5	3.56	3.55
T.S. 6 2" AC no ACFC	98.9	89.7	3.46	3.53
T.S. 4 ACFC over rubberized	111.5	91.9	3.44	3.51
T.S. 1 Rubberized Seal Coat	111.5	108.8	3.20	3.40
T.S. 11 Emulsion Treated Base	114.9	114.2	3.12	3.36

* Before Overlay
** Servicability Index
*** Rideability Index

TABLE 12
Rut Depth Values

Test Section	Feb. 1970 Before Overlay	May 1975
#2 Scarification & Petroset	.625	.125
#10 200/300 Pen	.875	.125
#12 Petromat	.375	.130
#5 Asbestos	.625	.150
#17 Reclamite Flush	.250	.150
Control	.750	.184
#15 Petroset in Cracks	.250	.200
#16 Reclamite in Cracks	.500	.200
#4 ACFC over rubberized	1.125	.210
#11 Emulsion Treated Base	1.000	.210
#3 ACFC over rubberized	.850	.225
#14 Petroset Flush	.500	.250
#9 120/150 Pen 4 Corner	.500	.260
#8 40/50 Pen	1.250	.290
#1 Rubberized Seal Coat	1.000	.360

Benkelman Beam	October, 1969	340 tests
Dynaflect	June, 1971	326 tests
Dynaflect	August, 1971	63 tests
Dynaflect	June, 1972	78 tests
Dynaflect	October, 1972	166 tests
Dynaflect	May, 1973	167 tests
Dynaflect	January, 1974	167 tests
Dynaflect	May, 1974	167 tests
Dynaflect	June, 1975	166 tests

To reproduce all test results would be quite lengthy; therefore, all results were compared in a manner similar to cracking and rideability. That is, the initial test set of June, 1971 was used as a base for percentage comparison. Deflections higher or lower than the initial value were determined as a percentage in accordance with the following equation:

$$\frac{\text{\% Deflection (Test N)}}{\text{\% Deflection (June, 1971)}} = \text{\% Relative Deflection}$$

A typical example is as follows:

DYNAFLECT DEFLECTION OF FIRST SENSOR IN MILS

Eastbound Station	June 71	Aug. 71	June 72	Oct. 72
302	0.81	0.65	1.02	1.14

PERCENT CHANGE IN DEFLECTION BASED ON JUNE 71

Station	Aug. 71	June 72	October 72
302	0.65/0.81 (80%)	1.02/0.81 (126%)	1.14/0.81 (141%)

By following this technique it was possible to succinctly display the trend of deflection values regardless of the magnitude of the initial deflection. Table 7A, Appendix A, gives the average initial deflection, the percent change in deflection and other pertinent values. In general, deflection values decreased after initial overlay and then began to steadily increase. Figure 15 displays this increase versus time, providing some insight into the overall deflection change with time. In addition, each test section and structural section deflection was reviewed. Figure 16 indicates percent change for all test sections. This form of analysis was selected since defelction characteristics are highly time dependent. In addition, percentage change was selected to null out any bias due to the varying magnitudes of deflection. As can be seen in Figure 16, up to May of 1973 performance of Test Sections 1 through 17 remained virtually the same. However, by January of 1973 deflections began to change, with Test Sections 14, 16, 17, and 18 doing poorly and Test Sections 1 and 3 doing very well. This trend continued throughout the test period. It is interesting to note that most test sections performed better than the overall average curve. This was to be expected since the overall curve includes two different projects with different structural sections. Performance of Test Sections 1, 3, 4, 5, 10, and 13, as of June 1975, could be indicative of their inherent waterproofing capacities, thereby limiting the access of water to the subgrade and reducing deflection.

It should be noted that those test sections which demonstrated minimum cracking were being subjected to considerable deflection by traffic. That is, they were preventing both reflected cracks and fatigue cracks.

For all test sections, structural design thickness was evaluated by deflection analysis. Figure 17 shows the percent change in eastbound deflections for the two overlaid projects (I 008-4 (3) and I 40-4 (15)). Both projects were overlaid with 1-1/4 inches AC and 1/2 inch ACFC. Deflections on Project I 40-4 (15) have increased at a remarkable rate and developed into a severe maintenance problem. In January of 1973, potholes began to appear on the eastbound portion of the I 40-4 (15) overlay project. District maintenance forces were concerned due to extensive patching required to cope with the problem. Later, in August of 1973, the Materials Division cored the highway and found that the old AC cake has stripped (asphalt washed off aggregate). Originally, the I 40-4 (15) highway had been constructed of a mineral aggregate which would now be considered a stripping aggregate. This particular aggregate is no longer considered a mineral aggregate under current stripping design criteria (11). The higher deflection recorded during this study is significant in that it indicates loss of structural support due to stripping.

For the westbound highway, change in deflections are plotted in Figure 18. This figure is significant in that it shows improved deflection performance for the 3-inch overlay section. This section would normally be considered as the strongest structural section and should indicate minimum deflection change, as indeed it does. The performance of westbound I 40-4 (15) has been noticeably better than the eastbound highway. That is, no potholes have occurred on this section. As can be seen from Figure 18, the percentage change in deflection is high, but not as high as the eastbound highway. It is possible that improved compaction and mix design of the westbound overlay is responsible, at least in part, for the improved performance.

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[11] Way, G., *A Study of the Arizona Design Criteria for the Prevention of Stripping of Asphalt Concrete,* Arizona Department of Transportation Report No. 6, (August, 1974).

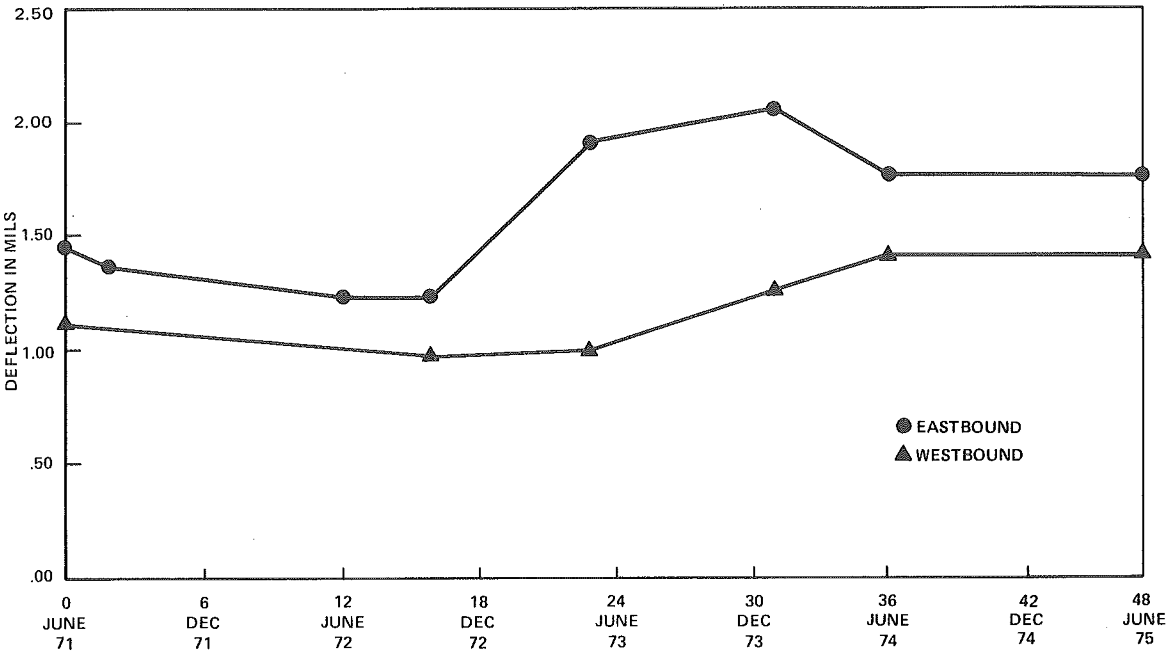

Figure 15. Average Deflection vs. Time

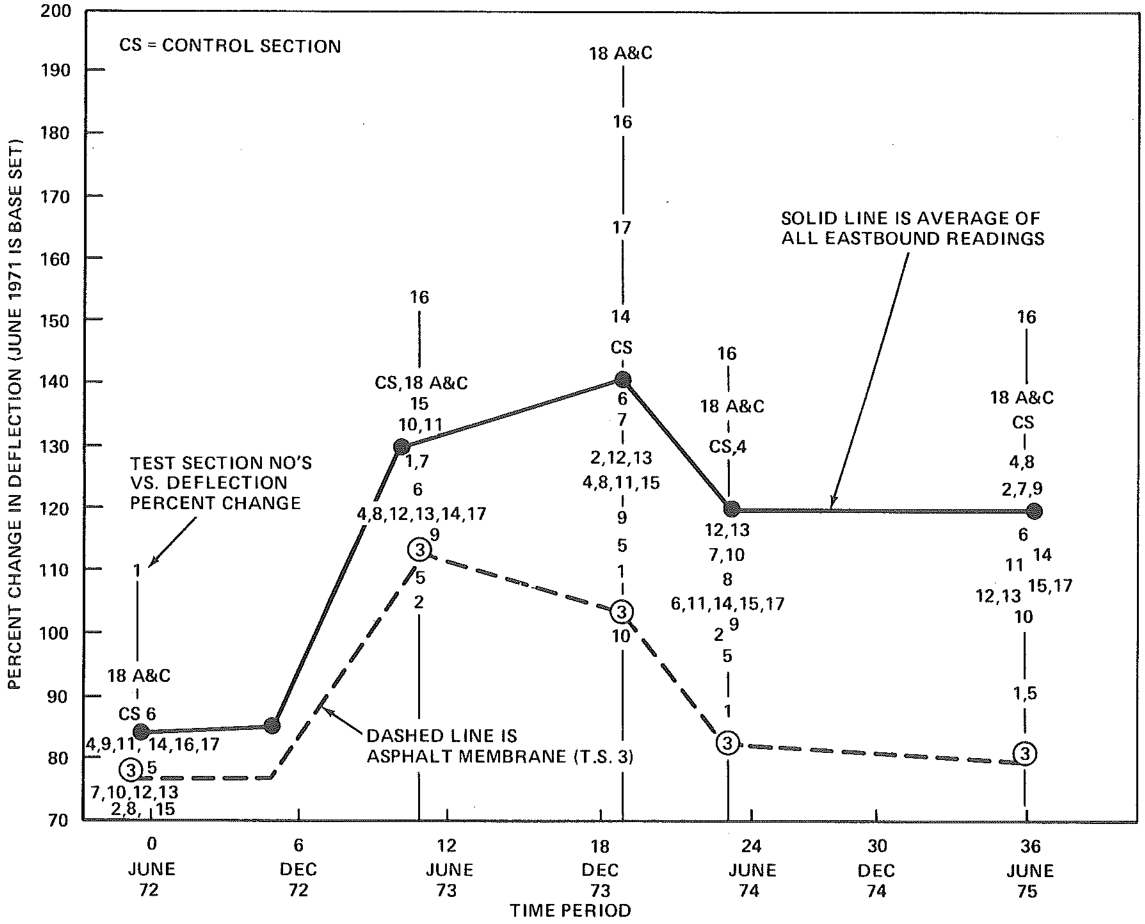

Figure 16. Deflection Performance – Percent Change, Comparison to Average Percent Change Curve

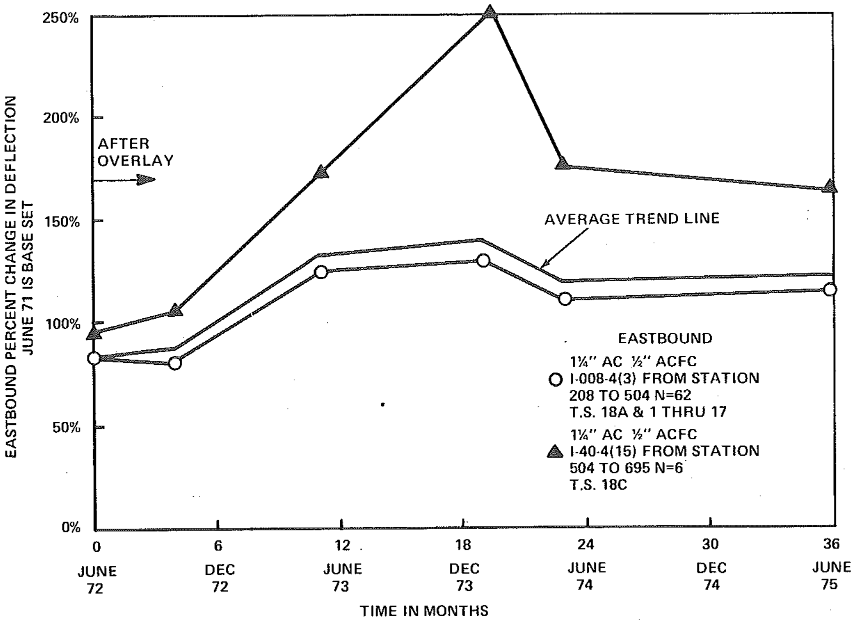

Figure 17. Deflection Comparison After Overlay (Eastbound)

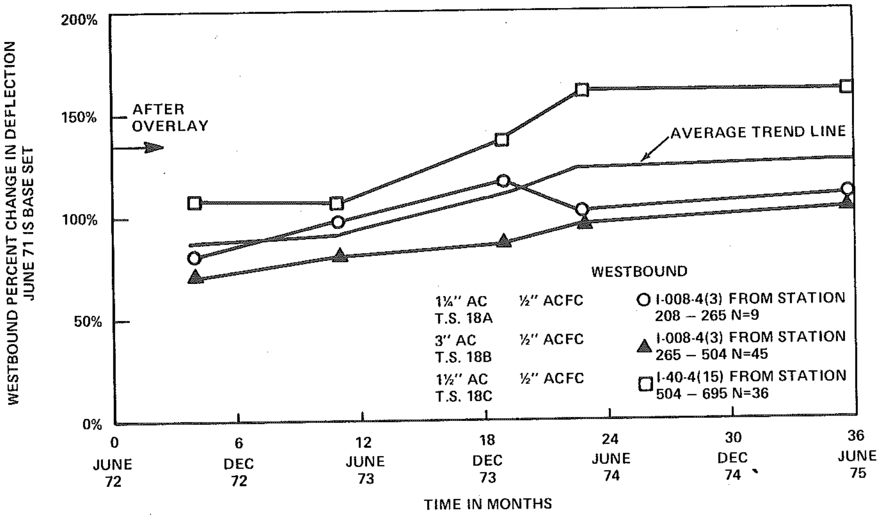

Figure 18. Deflection Comparison After Overlay (Westbound)

In general, deflection for all sections, treatments and thicknesses have increased with time. It is expected, however, that overlays placed over old pavements should reduce deflection. Several design curves showing percentage deflection increase with time have been published (12, 13). Experience on this project would indicate that the overlay did reduce deflection for approximately 6 to 12 months on the eastbound highway and 18 months on the westbound (1-1/4 inches AC and 1/2 inch ACFC section) highway. The 3 inch AC, 1/2 inch ACFC westbound section, however, reduced deflection for about 37 months. This would roughly equate to about 12 months of reduced deflection per inch of overlay. In reality the rate relationship is probably not linear, however, the real question is really how

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[12] Zube, E., and R. Forsyth, *Flexible Pavement Maintenance Requirements by Deflection Measurements,* Highway Research Board Report No. 116, (January, 1966).

[13] Bushey, R. W., K. L. Baumeister, J. A. Matthews and G. B. Sherman, *Structural Overlays for Pavement Rehabilitation,* California Department of Transportation Report No. TL–3128–3–75–02, (January, 1975).

much deflection is too much deflection. As evidenced in this project, deflection magnitudes varied considerably from one station to another, as well as with time. It is possible, however, that the inherent structure may or may not have changed with time. That is, each layer (AC, SM, Borrow) in most cases retained its given thickness with time (except for the stripping section). The load carrying ability of a given thickness of material did vary considerably with time. In no case (except for the stripping section) can it be said that this increase in deflection, by itself, had a significantly detrimental effect on the riding surface. We must therefore conclude that each structural section has a given capacity to withstanding loading as evidenced by the dynaflect. To explain this phenomenon, the magnitude of deflection for each section was reviewed. Figure 19 shows the actual magnitude of deflection versus time from before the overlay (June, 1971) to test completion (June, 1975). The eastbound section (Station 500-695) which is experiencing stripping has seen a tremendous increase in the magnitude of deflection. When potholing was first noted on the eastbound section (January of 1973), deflection readings on this section would have been approximately 0.90 mils. Deflections continued to rise to about 1.85 mils by January of 1974. Then, in the spring of 1974, considerable maintenance was performed with large sections (several hundred feet long) being removed and replaced with good patching material. The remaining eastbound section, which contains the majority of these test sections, experienced deflections in the order of 2.0 mils. It is amazing that these uncracked test sections have managed to perform under such conditions. The uncracked sections must be quite flexible. The westbound sections have not experienced the same magnitude of deflection as the eastbound. This is due to a thicker section (3 inches) in one particular case. However, the westbound I 40-4 (15) section is gradually increasing in deflection, but no potholing has been noted at the time of this report. As stated earlier, this could be due to the nature (compaction and mix design) of the AC on the westbound overlay.

Deflection values have also been tied to temperature (14). It is interesting to note that maximum deflections occurred in the winter of 1973–1974. However, it is also possible that some increase in deflection could be the result of rainfall.

In general, deflection values appear to be tied to the underlying materials, as well as environment. Thickness of AC layers surely has some influence, but apparently the existing AC layers seem incapable of limiting deflection at this time.

Skid Resistance

Skid resistance values were measured before, during and after overlay. All measurements were taken with a Mu-Meter, which has been subject to considerable use and evaluation in the past (15, 16). Skid resistance values are included in Table 8A, Appendix A.

Generally, skid values were quite high indicating excellent skid resistance. This can be attributed to the combination of cinder aggregate and the open graded ACFC mix.

Asphalt Properties

Considerable asphalt testing was performed during the course of the Minnetonka project, with asphalts from each treatment being tested during and after construction. Tests included:

- Microviscosity at 77°F
- Absolute viscosity at 140°F and 30 cm vacuum
- Penetration at 77°F
- Rapid rostler
- Vanadium content

The results of each test are shown in Tables 9A, 10A, 11A, 12A, 13A, 14A, and 15A of Appendix A, respectively. Table 9A shows microviscosity values for several different test sections. As can be seen, the 200/300 penetration and asphalt rubber have the lowest viscosity after three years service. Heater scarified sections are considerably higher in viscosity but still about the same as overlay values. In addition to actual viscosity values, limited work on temperature susceptability was performed.

Table 16A, Appendix A, shows microviscosity at various temperatures from 60°F to 140°F. Plotting these values on an ASTM standard viscosity chart for asphalts (D2493), results in relatively straight and parallel lines as shown in Figure 20. It would appear that with age the temperature susceptability curve shifts to higher viscosities. This being the

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[14] Southgate, H. F., *Temperature Corrected Deflection,* Kentucky Department of Highways.

[15] Burns, J. C. and R. J. Peters, *Surface Friction Study of Arizona Highways,* Arizona Department of Transportation (January, 1973).

[16] Burns, J. C., *Differential Friction Related to Skidding,* Arizona Department of Transportation, (April, 1975).

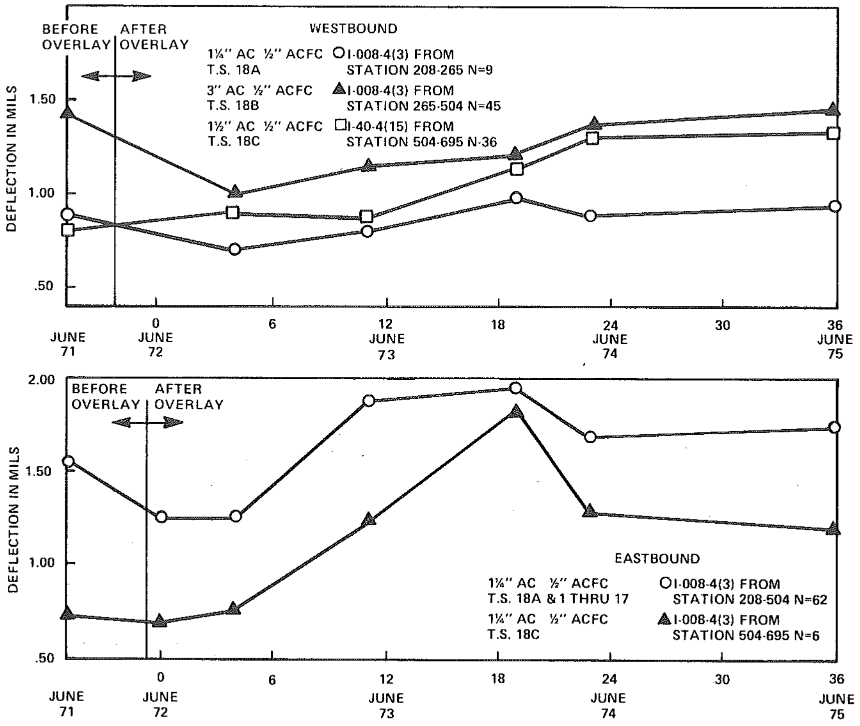

Figure 19. Increase in Deflection vs. Time

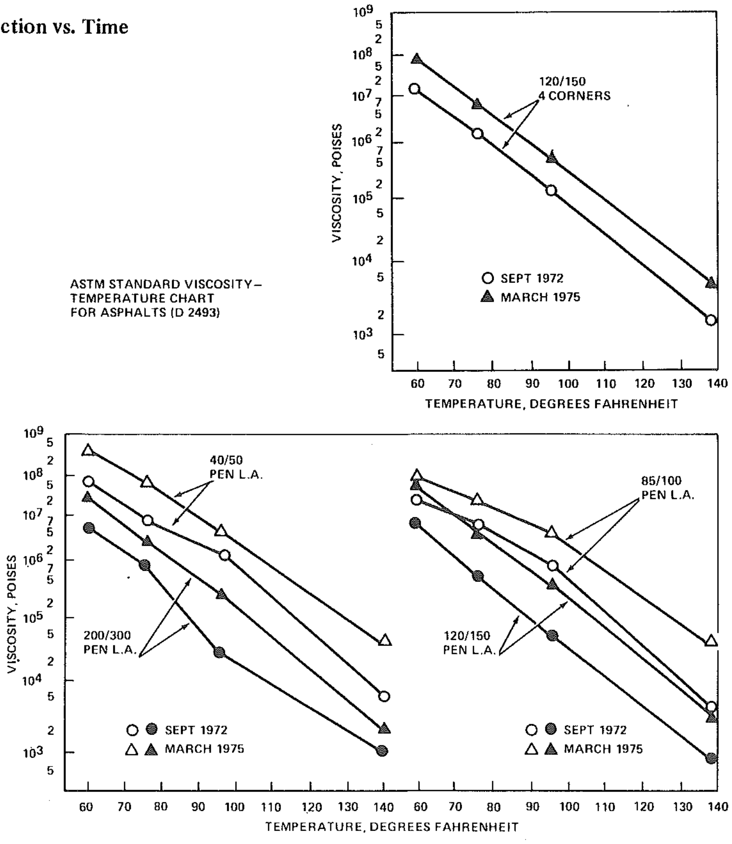
ASTM STANDARD VISCOSITY-TEMPERATURE CHART FOR ASPHALTS (D 2493)

Figure 20. Asphalt Viscosity vs. Temperature and Time

case, it is possible to select an arbitrary temperature for performance comparison. By selecting microviscosity at 77°F it was possible to plot percent reflective cracking versus microviscosity, Figure 21. Data points from Table 9A, Appendix A, were plotted for various test and control sections. Figure 21 roughly shows that for the Minnetonka test temperature conditions, asphalts need to maintain microviscosities below 4.0 mega poise (equivalent penetration about 45, or absolute unaged viscosity of 3000 poises at 140°F) as long as possible. The length of time an asphalt can maintain such a value is a function of its initial viscosity, film thickness, voids and particular aging characteristics. Figure 22 shows viscosity versus time for the different asphalt grades used in the configuration of 1-1/4 inches AC and 1/2 inch ACFC. Assuming the 4.0 mega poise region to be critical for crack initiation, Table 17A, Appendix A, was derived to determine length of time required to age asphalt to the 4.0 mega poise value. As Table 17A shows, Appendix A, very little time was needed to age most of the asphalts to a state where cracking could be initiated. The actual crack formation or intensity of cracking, as Table 17A demonstrates, apparently needs some additional catalyst to trigger crack formation. This catalyst is probably temperature, since reflective cracks tend to appear in the winter months. This being the case, the 4.0 mega poise value takes on the role of an indicator test which could point to future reflective cracking problems depending on temperature.

In referring earlier to asphalt aging characteristics Tables 12A, 13A, 14A, and 15A, Appendix A, were reviewed. From this review, it appears asphaltenes generally increased with time. Nitrogen bases and first Acidaffins generally increased as second Acidaffins and paraffins decreased. In the process of arriving at these final positions, Nitrogen bases and first Acidaffins decreased in September 1972, but by 1975 had increased substantially. The chemical or physical explanation for this activity is not available at this time. Table 15A, Appendix A, shows varying Vanadium amounts in each asphalt. Where only the 120/150 penetration 4-Corners asphalt has a low value, this being indicative of a slower aging asphalt which is true in this case. Comparing original to final viscosity grade, Table 15A gives the 120/150 penetration 4-Corners asphalt the lowest aging index. Unfortunately, as good as this may seem, this asphalt reached the critical asphalt viscosity at a relatively early age. Apparently, for crack control, both slow aging and low viscosity are necessary.

Considering the above observations to be true, a brief review of current asphalt specifications was in order. When the Minnetonka project was constructed, Arizona used the "penetration" specification. Since that time, the AR or Aged Residue specification has been adopted. Table 18A, Appendix A, gives the classification for each asphalt grade by penetration, AR grade (17), and AC grade (18). As can be seen, the 200/300 penetration asphalt could not be placed in Arizona under the AR grade without accessment of a penalty. In addition to the above asphalt examination, current asphalt products being used on projects since the AR grade was adopted were reviewed. Table 19A, Appendix A, contains absolute viscosity and penetration values before and after RTFO or C. As this table shows, both the AR 4000 and 2000 are close to the critical viscosity and penetration after 75 minutes in the RTFO or C. Generally it is accepted that this aged value relates to hot plant aging. This relationship was tested by using Figure 23 previously published in Arizona Research Report No. 4 (19). Figure 23 showed microviscosities for an 85/100 penetration LA asphalt and an 85/100 penetration 4-Corners asphalt, versus time in the RTFO. Times for equivalent microviscosities from Table 9A, Appendix A, and Figure 23 were plotted in Figure 24. From this, note that 75 minutes in the RTFO would have equated to one month of field aging or essentially the hot plant influence. In a limited sense, this figure equates the hot plant to 75 minutes in the RTFO. Likewise, 5 hours would equate to about 10 months. The shape of Figure 24 would indicate that each additional hour in the RTFO is substantially more severe in aging than actual field aging.

Previous research (20) has indicated that the penetration index and temperature ring and ball are important to initiation of transverse cracking. Table 20A, Appendix A, contains such values as derived from reference 20. Values would indicate the superior performance of 200/300 penetration asphalt.

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[17] "Asphalts; Paving, Liquid and Emulsified", *The Asphalt Institute,* (January, 1974).

[18] *Viscosity Graded Asphalt Cement,* AASHTO Materials Report No. M226-73, (1974).

[19] Peters, R. J., *Asphalt Cement Durability and Aggregate Interaction,* Arizona Department of Transportation Report No. 4, (April, 1973).

[20] Hajek, J. J. and R. C. G. Haas, *Predicting Low Temperature Cracking Frequency of Asphalt Concrete Pavements,* Department of Transportation and Communications of Ontario, (January, 1972).

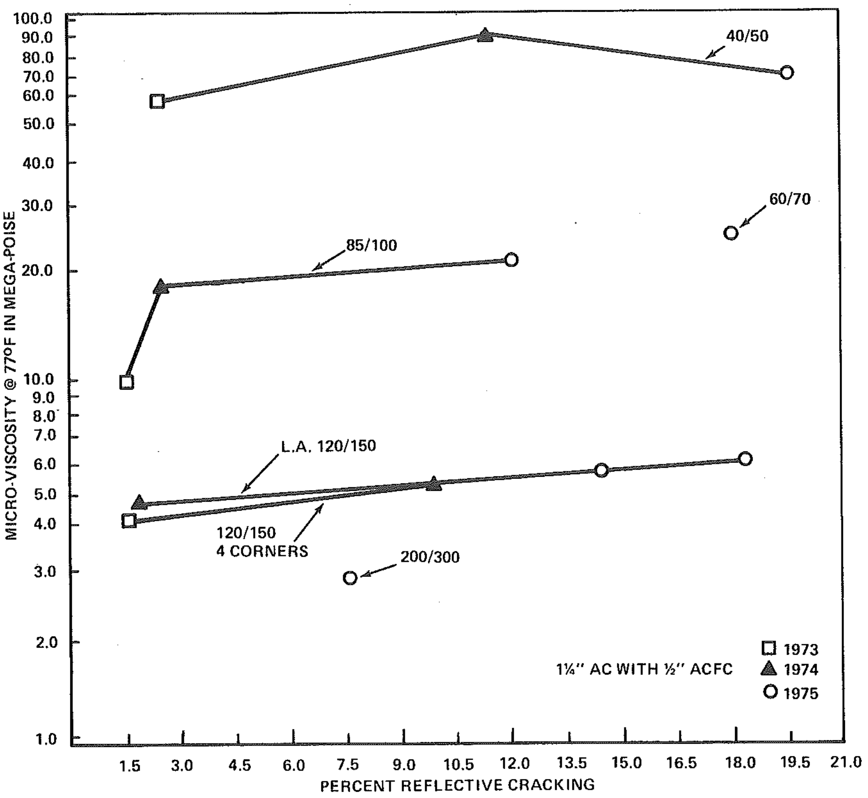

Figure 21. Percent Reflective Cracks versus Micro-Viscosity (T.S. 7, 8, 9, 10 and Control Sections)

In general it can be concluded that asphalt properties do have an influence on preventing reflective cracks. In summary, the combination of a low viscosity asphalt and a slow aging asphalt tailored to the ambient climatic condition can reduce reflective cracks.

This completes the review of performance test results. Knowing the above it is possible to analyze the mechanism (or the "why") behind the performance. The following section, Individual Test Section Analysis, will discuss the performance mechanism for each test section.

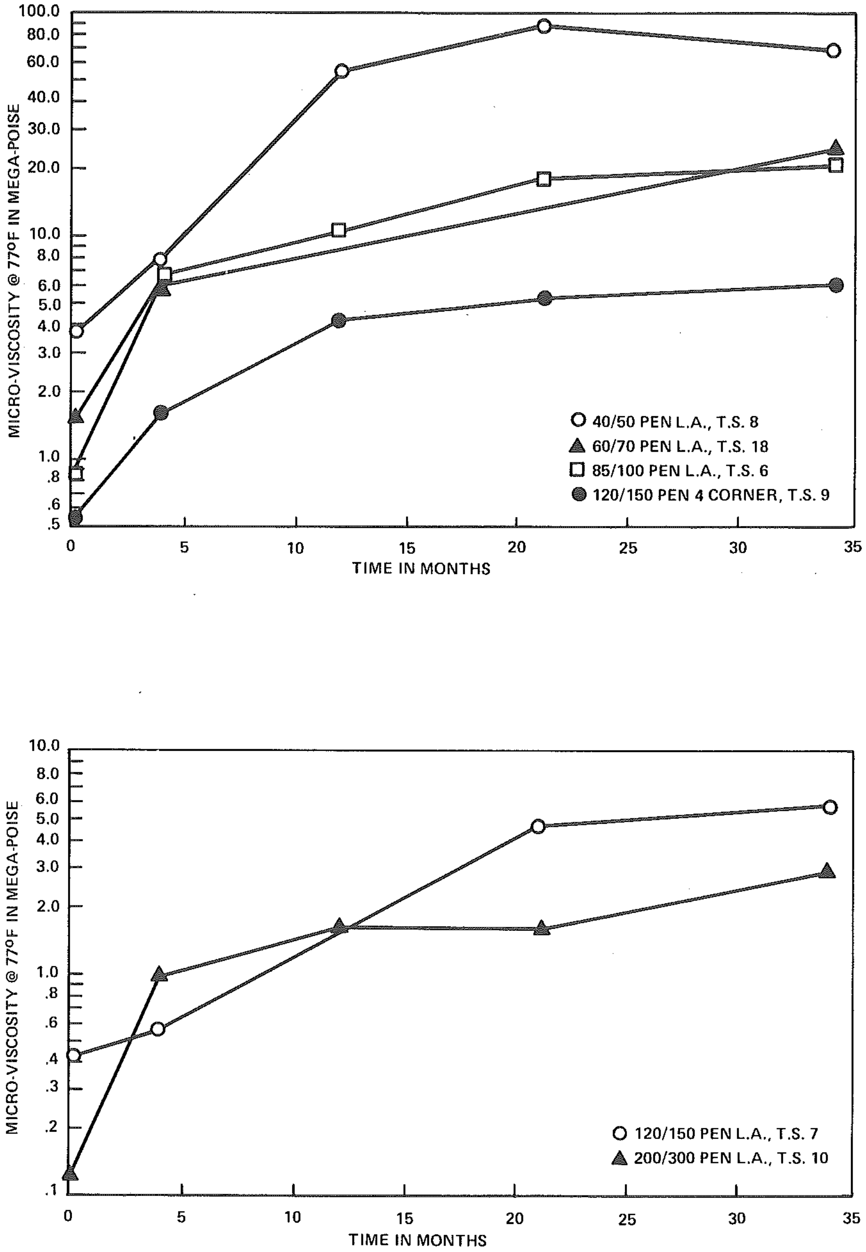

Figure 22. Asphalt Micro-Viscosity versus Time

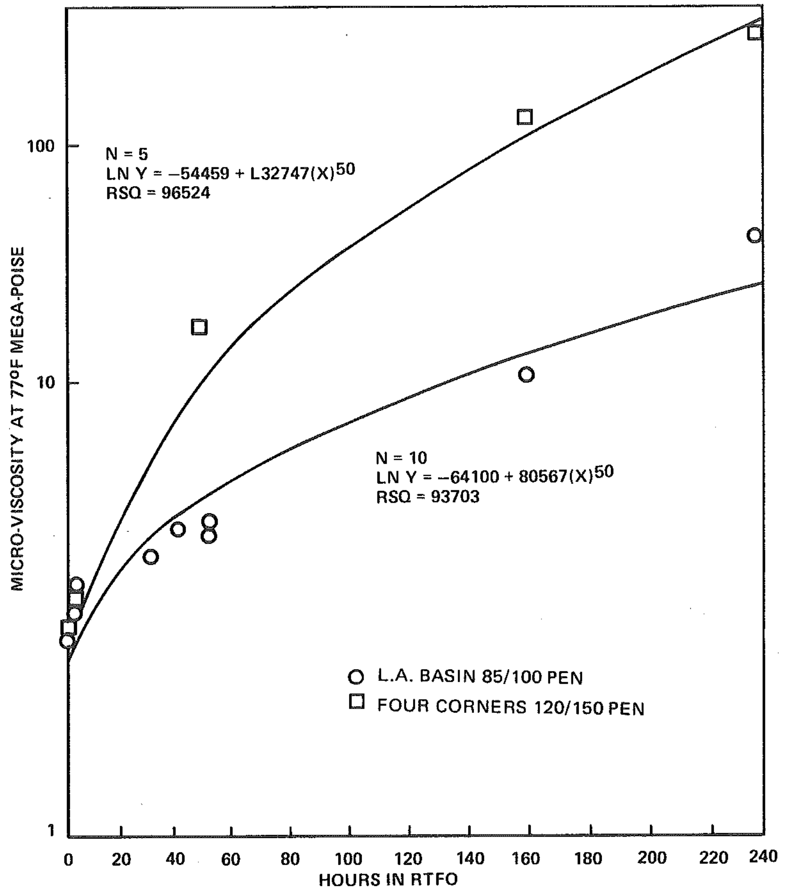

Figure 23. Asphalt Micro-Viscosity vs. Hours in RTFO (For Slow and Fast Aging Asphalts)

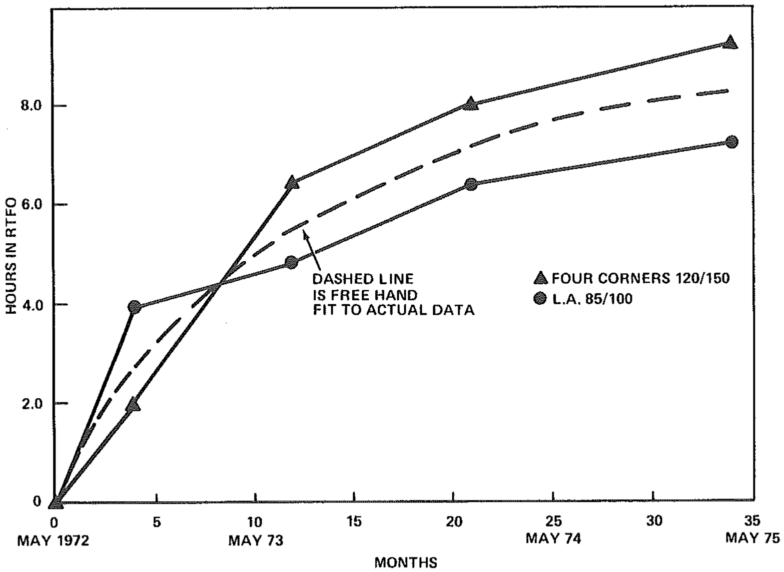

Figure 24. RTFO Time vs. Field Time (To Achieve Equivalent Micro-Viscosities @ 77°F)

Individual Test Section Analysis

Reference should be made to Tables 3, 4, and 5 for individual test section construction and treatment specifications, while Appendix B provides in-depth material and process specifications.

Test Section No. 1: Asphalt rubber seal coat with precoated chips placed on AC, no ACFC.

In analyzing crack performance, it became clear with time that this test section, with no ACFC, could not be equally compared with those sections having an ACFC. As such it was compared to Test Section No. 6 (2 inches AC overlay, no ACFC). See Tables 8 and 9, and the following text for explanation of ACFC in preventing cracks.

T.S. No. 1 did prevent flexural cracks; however, shrinkage cracks did reflect.

Rideability values computed and shown in Table 10 indicate T.S. No. 1 to be one of the roughest sections. Although no value in the table is terminal, it should be remembered that the original roughness was also not terminal. Table 11 shows that T.S. No. 1 is as rough now as before construction. In essence, this means that seal coats placed on top of thin overlays have little ability to improve the ride.

T.S. No. 1 also produced the greatest rut depth. This is probably due to the unintended high application rate of asphalt rubber (1 gallon/yd^2). Such a tender material as this was bound to move under loading, particularly the channelized loading found on an interstate.

Figure 16 shows the percent change in deflection was less. This decrease could be the result of reduction in moisture entering the section and as such could be an added long term benefit.

Asphalt properties, Table 9A, Appendix A, indicates the asphalt is aging very slowly. Some question as to the validity of these test results has recently been raised. Recent chemical research by ADOT (21) shows that extraction of asphalt rubber mixtures with hot solvents brings out extender oils from the ground tire rubber bits. Such oils could reduce viscosity measurements considerably. This new finding makes analysis somewhat complicated at this time. As such, the rubberized seal will continue to be analyzed as aging very slowly, if for no other reason than the nature of the application. A one gallon/yd^2 mixture of rubber and asphalt equates to about a 1/4 inch thick layer of practically voidless material. This being the case, aging should be very slow. In addition the rubber bits contain anti-oxidants which could also slow aging.

The above remarks have dealt with the asphalt phase of the asphalt rubber mixture. The asphalt rubber mixture has considerably different properties than the asphalt alone; that is, the mixture has a much flatter temperature susceptibility curve (22), and in addition, has elastomeric properties. These properties allow the mixture to be stretched by loading, and when the load is removed the mix will pull back to its original shape. Asphalt alone does not have this property.

In summary, T.S. No. 1 did prevent flexural cracks, however, it did not control shrinkage cracks. Ride was poor, there was considerable rutting and deflection was only slightly reduced.

Test Section No. 2: Heater scarification plus Petroset, followed by overlaying with AC and ACFC.

This treatment significantly reduced reflective cracks. The apparent success stems from the scarification process, which opens up the top 3/4 inch of pavement allowing the Petroset to penetrate and rejuvenate. The remolded portion destroys the old crack pattern to a depth of 3/4 inch, plus it increases overlay section thickness by 3/4 inch. Those cracks that have reflected through are almost always longitudinal in nature. Apparently the scarification process, by nature, has difficulty in disrupting the longitudinal crack structure.

Assuming this analysis is true, it may be possible to reduce overlay thickness to that necessary for leveling only. In some cases such leveling could be done with just an ACFC.

Rideability values fall in the very good category, with rut depth being very shallow. No discernable trend in deflection can be seen; that is, this section appears to experience the same magnitude of deflection as all the others. Table 9A, Appendix A, on asphalt properties might lead to the conclusion that this section should crack. However, it should be remembered that reported values refer only to the

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(21) Green, E., *Chemical and Physical Properties of Rubber Asphalt Mixes,* Arizona Department of Transportation Report No. HRP–1–13 (162).

(22) Morris, Gene R. and Charles H. McDonald, *Asphalt-Rubber Stress Absorbing Membranes, Field Performance and State-Of-The-Art,* Arizona Department of Transportation, (March, 1976).

3/4 inch heater scarified section. At present this section still has a microviscosity lower than the original pavement. This, coupled with the action of the scarification process, is apparently sufficient to prevent cracks. In summary T.S. No. 2 is preventing cracks without excessive roughness or rutting.

Test Section No. 3: Asphalt Rubber Membrane seal coat between the AC overlay and ACFC.

This treatment is preventing reflective cracks, the mechanism being a combination of several physical and chemical phenomenon. The application of a rubberized seal coat amounts to the placement of a 1/4 inch layer of asphalt rubber and aggregate. This can be accomplished because of the high bulk viscosity of the mixture. The asphalt phase remains extremely pliable, much like its original viscosity, even after several years in service. This is due to practically no air voids in the 1/4 inch layer, and no exposure to sunlight (because the layer is under a 1/2 inch ACFC). These conditions keep the asphalt and rubber in a state similar to when they were initially placed. This extremely flexible layer can easily accommodate the stresses imposed by a crack forming in the AC. It is possible that the asphalt rubber mixture could even partially fill the void caused by a small crack. Provided this is true, it may be possible to reduce overlay thickness to that necessary for leveling only. This could be followed by asphalt rubber and an ACFC.

Rideability does suffer somewhat with this treatment. This is only natural when it is considered that the 1/2 inch ACFC must level any loss in ride (roughness) due to placement of a chip seal. Chip seals are placed as irregular surfaces and do introduce a degree of roughness.

Rut depth is not excessive and is partly due to some distortion due to loading. This phenomenon was explained under T.S. No. 1 and is partly mitigated by the ACFC.

Deflections tend to be lower in this section as in T.S. No. 1. This is probably due to a decrease in moisture. The main consideration, as in all test sections, is the magnitude of deflection. All test sections are being subjected to tremendous deflection.

With respect to asphalt properties, comments similar to T.S. No. 1 are in order. Aging in this section is slower than T.S. No. 1 and perhaps slower than any of the other sections. This is due to both physical (lack of voids) and chemical (lack of sunlight) considerations.

In summary, the use of rubberized asphalt under ACFC does prevent reflective cracks. Some loss of ride and rutting does occur, but neither is serious.

Test Section No. 4: Asphalt Rubber seal coat between the AC Overlay and ACFC.

Same analysis as T.S. No. 3.

Test Section No. 5: AC overlay with 3.2% asbestos filler added and an additional 3% asphalt added to mix. 1/2 inch ACFC.

Reflective cracking was found to be less than the control sections. Since previous experience in Arizona with asbestos before Minnetonka was non-existent, Johns Manville Corporation was asked to design a suitable mix for the cinder mineral aggregate being used on the Minnetonka Project. Johns Manville was kind enough to cooperate and after extensive testing recommended the following:

"The following mixes are recommended on the basis of strength, dimensional stability and surface properties; It is suggested that both mixes be placed for comparative studies.

	% Total Weight of Mix	
	Fiber Content	**Asphalt Content**
1st Choice	2.5	13.5
2nd Choice	4.0	14.0

Use of asphalt grades above 100 penetration are not recommended with asbestos. Surface porosity of these aggregates requires higher asphalt and fiber content than would be normal for dense aggregates. Angularity of the aggregate is excellent for pavement surface texture, but may limit resistance to reflection cracking. A blend of semi-rounded natural sand with the coarser graded stone might be preferable in both respects."

The use of a 60/70 penetration asphalt was in keeping with Johns Manville's recommendation, however, it appears a much higher penetration or lower viscosity asphalt should have been used.

Ride appears quite acceptable on this section (Table 11). Rut depth is shallow (Table 12). Apparently the intended design was aimed at keeping the stability of the mix high, thereby insuring against rutting. In this respect the design was quite acceptable.

Deflection tended to be lower. This could be due to the waterproofing action caused by increasing the percent binder, thereby reducing the air voids to about 2% percent.

Asphalt aging was considerably slower here than in comparable T.S. No. 18 which was built with 60/70 penetration asphalt, Table 9A (Appendix A). Unfortunately the asphalt aged sufficiently by 1974 to increase its microviscosity above the 4.0 mega poise level.

Performance of this test section was more than acceptable up to 1975 when cracking was noted. This treatment could continue to be acceptable provided a lower viscosity (high penetration) grade asphalt had been used during construction.

Test Section No. 6: 1-3/4 inch AC, no ACFC, 85/100 penetration asphalt.

This section has exhibited more cracking than all the other sections, with over 60 percent of the original cracks having been reflected. Ride is about the same now as before overlaying (Table 10). Rut depth was not measured on this section, however, deflection did tend to follow the average trend. Asphalt aging has been quite rapid, Table 9A (Appendix A).

In summary, this is the poorest performing section. Part of the reason for this is given in the T.S. No. 1 analysis; that is, dense graded overlays with no open surfacing course are the most prone to show reflective cracks. In such overlays no attempt is made to prevent cracking. The overlay physical properties are virtually the same as the old pavement. In addition, the closed or dense texture of the surfacing is more likely to show all cracks, no matter how small. In effect, this section represents the "incorrect thinking" that overlaying with a dense AC mix by itself can stop cracking.

Test Section No. 7: 1-1/4 inches AC with 120/150 penetration LA asphalt, 1/2 inch ACFC.

Prevention of cracks was only slightly better than the control section. Ride was quite acceptable. Rut depths were not measured, and deflection tended to be about average. Asphalt aged to the 4.0 mega poise level by 1974 and corresponding cracking was evidenced.

Performance is tied closely to asphalt properties.

Test Section No. 8: 1-1/4 inches AC with 40/50 penetration LA asphalt, 1/2 inch ACFC.

Cracking very bad. Ride acceptable. Rut depth, second deepest. The deeper rut depth must be attributed to cracking since a high-viscosity asphalt is not very likely to rut. Deflection tended to follow the average trend line. Asphalt properties were the key to this section's poor performance. After placement, asphalt viscosity was high enough to initiate cracking. As Table 8 shows, cracks started the first winter.

Test Section No. 9: 1-1/4 inch AC, 120/150 penetration 4-Corners asphalt, 1/2 inch ACFC.

This section cracked more than the control sections. Ride was more than acceptable, however, rut depth was quite large. Again rut depth appears to be related to cracking, although the asphalt in this section is still probably lively enough to undergo some deformation. Deflection tends to follow the average trend line. Asphalt properties are good, except the critical 4.0 mega poise value was reached in 1973.

Performance was not good, which was quite remarkable. Slow aging did occur, but, unfortunately was not slow enough. What this test section tells us is; both low viscosity and slow aging are necessary to prevent reflective cracks.

Test Section No. 10: 1-1/4 inch AC, 200/300 penetration LA Basin asphalt 1/2 inch ACFC.

A significant reduction in reflective cracks was noted. Smoothest ride of all sections and one of the shallowest rut depths. Deflections tend to follow the average trend line. Asphalt properties are very good with the asphalt still not at the critical 4.0 mega poise level.

Overall performance was very good in virtually all categories. Eventually, after sufficient asphalt aging, significant cracking will take place. If current aging trends continue such cracking would come next year.

Test Section No. 11: 1-1/4 inch open graded cold mixed asphalt, emulsion treated AC, 1/2 inch ACFC.

Cracking was only slightly less than the control sections. Poor ride performance was undoubtedly due to blade placement of the AC. The ACFC was not able to iron out or level up the irregularities of blade placement. Rut depth was not excessive and deflection was about average. Asphalt properties are somewhat hard to analyze due to the flush coat application. It appears, however, that significant aging did take place rather rapidly. The use of a 40/50 penetration asphalt as a base stock did not help the cracking.

This section was the only one on the I 008-4 (3) roadway that required patching. That is, once the ACFC skin was broken, significant potholing occurred, requiring removal and replacement.

Test Section No. 12: Petromat, 1-1/4 inch AC, 85/100 penetration asphalt, 1/2 inch ACFC.

This section experienced slightly less cracking than the control section. Cracks did reflect through the Petromat and were longitudinal in nature. Ride values were very good. Part of this smooth ride results from the inherent strength of the Petromat, which is quite strong and very flexible. Rut depth was shallow and deflection followed the average trend line. Asphalt properties were not investigated as it was thought that most of the inherent properties were tied to the Petromat.

Performance was good but not exceptional. Cracking apparently was due to a lack of balance between strength properties of Petromat and AC. For Petromat to work it should be used in conjunction with the thinnest most flexible surfacing, perhaps a seal coat. Experience reported by the Army Corp (23) would indicate such a surfacing is possible.

Test Section No. 13: Fiberglass, 1-1/4 inches AC, 85/100 penetration asphalt, 1/2 inch ACFC.

This treatment significantly prevented reflected cracks. Ride was very good and no rut depths reported. Deflection tended to follow the average trend line. Asphalt properties were not investigated since performance properties were thought to be related to the fiberglass.

Performance was very good. Prevention of cracking here compared to T.S. No. 12 would indicate that fiberglass is a better material than Petromat. Yet tests show the fiberglass rovings to have virtually no tensile strength. In this respect, fiberglass appears to act like a sponge allowing the placement of a thick layer of asphalt. If this analysis is correct, use of fiberglass or Petromat should be coupled to applying as much asphalt to these porous materials as they can physically accommodate, in this way developing a very thick flexible layer similar to T.S. No's. 3 and 4.

Test Section No. 14: 1-1/4 inches AC, 85/100 penetration asphalt, Petroset flush, 1/2 inch ACFC.

Experienced slightly less cracking than control section. Ride was also equivalent to control section and rutting about average. Deflection tends to follow average trend line. Asphalt properties probably similar to T.S. No. 1.

Performance at best only fair. This was the manufacturers suggested use of Petroset, which did not significantly improve performance over the control sections. The low application rate of the flush could not possibly have altered the overlay properties enough to bring about any significant improvement.

Test Section No. 15: Petroset in cracks, 1-1/4 inches AC, 85/100 penetration asphalt, 1/2 inch ACFC.

This section prevented cracks only slightly better than control section. Ride was about the same as the control section. Rut depth also was equivalent to the control section. Deflection followed the average trend line. Asphalt properties were not investigated.

Performance was very similar to the control section. Application of Petroset to cracks probably had about the same impact as normal maintenance refilling or sealing of cracks.

Test Section No. 16: Reclamite in cracks, 1-1/4 inches AC, 85/100 penetration asphalt, 1/2 inch ACFC.

Reflective cracking was bad. Ride and rut depth were slightly worse than the control section and deflections were higher than the average trend line. Asphalt properties were not investigated.

Overall performance was worse than the control section. Such performance is hard to equate to T.S. No. 15. However, the author feels the application technique could have had some impact. Reclamite was sprayed on cracks, whereas, Petroset was streamed into cracks.

Test Section No. 17: Reclamite flush, 1-1/4 inches AC, 85/100 penetration asphalt, 1/2 inch ACFC.

Here again, cracking was similar to the control section. Ride and rut depth values were slightly better

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[23] Burns, C. D., W. N. Brabston and R. W. Grau, *Feasibility of Using Membrane-Enveloped Soil Layers as Pavement Elements for Multiple-Wheel Gear Loads,* U. S. Army Engineer Waterways Experiment Station Soils and Pavements Laboratory, Vicksburg, Mississippi, Paper S–72–6, (February, 1972).

than the control section. Deflections tended to follow the average trend line. Asphalt properties were not investigated.

Overall performance was similar to T.S. No. 16. The three treatments of T.S. No's. 15, 16, and 17 could have been influenced by the seven month time lag between application and overlay, although many control sections sat through the same period, yet tended to perform as well. Apparently it was necessary to break up the old crack pattern as well as rejuvenate.

Test Section No. 18A: Heater scarifying, reclamite flush, 1-1/4 inches AC, 85/100 penetration asphalt, 1/2 inch ACFC.

Stationing: Eastbound Stations 208–260, 265–280
Westbound Stations 208–265

Significant reduction in reflective cracking. Ride good and no rut depths recorded. Deflection varied with old projects. Asphalt properties remain better than original pavement.

Performance was virtually the same as T.S. No. 2.

Test Section No. 18B: Heater scarification, reclamite flush, 3 inch AC, 85/100 penetration asphalt, 1/2 inch ACFC

Stationing: Westbound Stations 265–270, 275–400, 405–504

Reflective cracking was significantly reduced. Ride was good and deflections were reduced as previously explained.

Performance similar to T.S. No's 2, 3, 4, 10, 13, and 18A.

Test Section No. 18C: I 40-4 (15) Heater scarification, reclamite flush, 1-1/2 inches AC, 85/100 penetration asphalt, 1/2 inch ACFC.

Stationing: Eastbound Stations 504–600, 605–692
Westbound Stations 504–530, 535–660, 665–692

Considerable potholing was experienced in the eastbound travel lane. Many large patches were required as well as a seal coat. Deflection was quite high.

Stripping of old pavement occurred after overlay. This behavior could possibly have been predicted by source of mineral aggregate used in old pavement. The material used is now considered a stripping aggregate and is unsuitable for mineral aggregate.

The fact that both the eastbound and westbound roadways were built out of the mineral aggregate and the eastbound stripped while the westbound did not strip, leads to the observation that the difference in compaction of the eastbound and westbound highways could have an influence on stripping. That is, overlays built over potential stripping aggregates need to be densified to at least 92 percent of the maximum theoretical density or higher.

This concludes the test analysis section. The next section will discuss cost considerations and maintenance requirements.

Cost Considerations

After the completion of construction, the costs of each treatment was computed as based on bid item values. As would be expected, these costs were high due to the experimental nature of the project. Also, it should be noted that the base costs of asphalt products have increased significantly over the past two years, with AC costs having increased considerably.

Other cost effects include such items as the heater scarification process which now uses bottled gas as well as diesel fuel. These changes, coupled with Arizona's subsequent use of several of these treatments on subsequent projects, prompted the author to update all cost figures as based on current 1975 values.

Table 13 presents high, low and average cost figures as extracted from project bids (See Table 22A, Appendix A). The four subject classifications as presented represent a large number of major projects constructed over the past few years. The cost from Table 13 were considered as building blocks where the average values were used to construct typical costs for various treatments. Other treatments, where historical cost information was not available, were estimated primarily from manufacturer's literature.

Table 14 contains the cost of each treatment by square yard, and per lane mile (12 foot wide). These costs reflect the total of all ingredients and operations and are estimations based on a nominal size job (Generally more than 40,000 square yards of surfacing). As the table shows those treatments that cost less than the control section generally performed worse except for the 200/300 penetration asphalt. Treatments costing more than the control section generally performed better. AC sections of 3, 4, and 7 inch thickness are shown to relate to the 3-inch thick section on the project and to Finn's (24) 4 inch or more recommendation and the 7 inch section mentioned by Texas (25). When related to the test results, Table 13 shows the degree of crack reduction is not necessarily commensurate with increase in cost. To help complete the economic picture, maintenance costs have also been considered. Table 21A, Appendix A, shows maintenance costs versus time. It was impossible for maintenance to keep records on a treatment basis, therefore, only broad station location sections could be given. As Table 21A shows, considerable funds have been used. To help explain the meaning of these cost figures, maintenance costs per mile have been plotted versus time for the control sections (1-1/4 inches AC, 1/2 inch ACFC), proposed treatments, and the 3 inch AC section (Figure 25). As this figure shows, as of June, 1975, the cumulative cost to maintain the conventional overlay was $8,900/mile without stripping and $15,000/mile with stripping of the old AC. Put another way, the total cost/square yard has increased as Table 15 indicates.

TABLE 13
Historical Project Cost Summary

Subject - Classification	Cost per square yard			
	N	Average	High	Low
1" of AC in-place	29	$.790	$1.278	$.516
½" of ACFC in-place	24	.577	.995	.338
Heater scarification plus reclamite	29	.346	1.129	.286
Asphate rubber plus chips	13	.750	1.826	.522

N = number of project bids considered

As can be seen from Table 15, special crack preventing treatments are beginning to look favorable in price when viewed against the cumulative maintenance cost figures.

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[24] Finn, F. M., K. Nair and J. Hilliard, *Minimizing Premature Cracking of Asphalt Concrete Pavements,* Material Research and Development Report, (November, 1972).

[25] Lu, D. Y., R. L. Lytton and W. N. Moore, *Forecasting Serviceability Loss of Flexible Pavements,* Texas Transportation Institute Research Report No. 57–1F, (November, 1974).

TABLE 14
Cost of Overlay Plus Treatment

	Cost/Yd^2	*Cost/Lane Mile
T.S. #11, Emultion Treated Base	$1.24	8,730
T.S. #7, 120/150 Pen L.A.	1.56	10,982
T.S. #8, 40/50 Pen L.A.	1.56	10,982
T.S. #9, 120/150 Pen 4-Corners	1.56	10,982
T.S. #10, 200/300 Pen L.A.	1.56	10,982
Control Section 1-¼" AC, ½" ACFC	1.56	10,982
T.S. #6, 2" AC no ACFC	1.58	11,123
T.S. #15, 16 & 17 Reclamite & Petroset in Cracks or as Flush	1.62	11,405
T.S. #14, Petroset as flush	1.65	11,616
T.S. #1, Rubberized Chip Seal	1.74	12,250
T.S. #5, Asbestos	1.81	12,742
T.S. #2 & 18A, Heater Scarified plus Reclamite or Petroset 1¼" AC, ½" ACFC	1.91	13,446
T.S. #3 & 4 Asphalt Rubber over 1¼" AC and under ½" ACFC	2.32	16,333
T.S. #12, Petromat	2.41	16,966
T.S. #13, Fiberglass	2.45	17,248
T.S. #18B, Heater Scarified plus Reclamite, 3"AC, ½" ACFC	3.29	23,162
3" AC, ½" ACFC	2.95	20,768
4" AC & ½" ACFC	3.74	26,330
7" AC & ½" ACFC	6.11	43,014

*Lane Mile equals 12′ x 5280′ = 7040 Square Yards

TABLE 15
Construction and Maintenance Costs Summary

	Cost/Yd^2 At Construction	Cost/Yd^2 of Construction Plus 3 years of Maintenance
1¼" AC Overlay with ½" ACFC No Stripping of Old Pavement	$1.56	$2.19
1¼" AC Overlay with ½" ACFC with stripping of Old Pavement	1.56	2.63
1¼" AC Overlay with 200/300 Pen. Asphalt Plus ½" ACFC	1.56	1.68
Heater Scarification with 1¼" AC Overlay Plus ½" ACFC	1.91	1.99
Asphalt Rubber Seal Coat on top of 1¼" AC and under ½" ACFC	2.32	2.36
Fiberglass with 1¼" AC Overlay and ½" ACFC	2.45	2.51
Heater Scarification with 3" AC Overlay Plus ½" ACFC	3.29	3.41

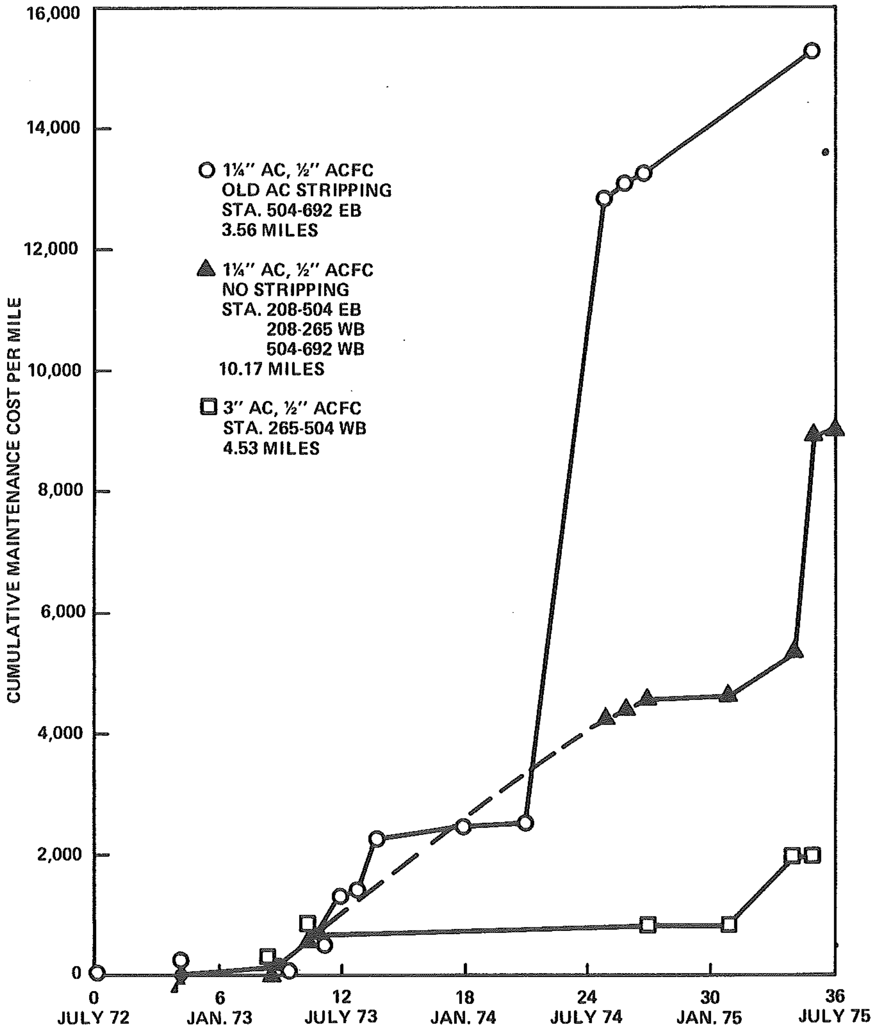

Figure 25. Maintenance Costs

General Conclusions

The Minnetonka-East project was initially constructed to determine whether one or more of a variety of treatments could prevent or significantly reduce reflective cracking. However, little has been said about why the initial cracks formed. Put another way, no degree of difficulty has been assigned to this project with regard to a particular overlays chance of preventing reflective cracks. It was considered that this stretch of interstate represented some of the most severe cracking in the state. As such, it was anticipated that any overlay, especially a thin one, would crack very early in its life. There was good reason for this expectation. First the original project I 008-4 (3) was originally opened to traffic during August, 1958. By November, 1967, the roadway had deteriorated to a point that the District requested an overlay. Pictures taken during February, 1969, showed a very badly cracked and rutted pavement. In essence the original pavement of 3.5 inches AC and 3 inches BTB was distressed in about 7 to 8 years. Assuming an overlay would give comparable results on an inch-per-inch of AC basis, a 2-inch overlay would last about two years. Obviously such a linear relationship is somewhat unfair. That is, by the same logic, a 7-inch overlay would last approximately 8 years; therefore, to achieve 20 years of life, an overlay would dictate about 20 inches of pavement. More than likely, however, the true relationship is quite curvilinear in nature. Whatever the true relation, 2 inches of AC probably would not equate to very many years of service. With this in mind, the ability of some treatments to perform as well as they did is remarkable.

The performance perspective changes when the I 40-4 (15) project is observed. This project, built in 1962, was not nearly as distressed as I 008-4 (3) in 1971 (when overlayed). It was expected that a thin overlay would perform quite well on the I 40-4 (15) project. Unfortunately stripping of the old AC occurred after overlaying, and instead of having 4 inches of old AC with a 1-3/4 inch overlay, now a 1-3/4 inch surfacing was carrying the interstate load. Results were painful to witness. Several miles of overlay were then, and are still being patched and sealed. The condition of the eastbound section of I 40-4, after overlay, is considerably worse. This peculiar problem of stripping is not new to Arizona. Much work has been done to guarantee against stripping problems on new AC (26) built after 1968. Unfortunately the problem of old pavements had not been thoroughly investigated before overlaying or seal coating.

General Performance Overview

The following is a general review of all performance criteria as experienced during the Minnetonka-East project. This review considers each test section and its respective treatment, followed by a brief discussion of other parameters, including:

- Reflective Cracking Ranking
- Asphalt Concrete Finish Course (ACFC)
- Rideability
- Rutting
- Deflection
- General Asphalt Properties
- Stripping – Original Pavement
- Cost Considerations

General Test Section Performance

Test Section No. 1: Asphalt rubber seal coat with pre-coated chips, placed on 1-1/4 inch AC overlay, no ACFC.

- Prevented flexural cracks but did not control shrinkage cracks
- Ride poor
- Considerable rutting
- Deflection was reduced and remained so with time
- Asphalt aging very slow, with viscosity of asphalt below 4.0 mega poise at 77°F

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[26] Finn and Nair, *Development of Pavement Structural Subsystems,* Material Research and Development Report. No. NCHRP–1–10B.

Test Section No. 2: Heater scarification plus Petroset, followed by overlaying with 1-1/4 inch AC and 1/2 inch ACFC.

- Prevented reflective cracks
- Ride good
- Little rutting
- Deflection increased with time
- Asphalt in heat scarified area aged rapidly

Test Section No. 3: Asphalt rubber membrane seal coat placed over 1-1/4 inch AC overlay, and under 1/2 inch ACFC.

- Prevented reflective cracks
- Ride good
- Little rutting
- Deflection reduced and remained so with time
- Asphalt aging very slow and viscosity remains below 4.0 mega poise at 77°F

Test Section No. 4: Same as Test Section No. 3.

Test Section No. 5: 1-1/4 inch AC overlay with 3.2% asbestos filler added, and an additional 3% asphalt added to AC mix, 1/2 inch ACFC.

- Slightly less cracking than control sections
- Ride good
- No rutting
- Deflection reduced and remained so with time
- Asphalt aged to a value above 4.0 mega poise at 77°F

Test Section No. 6: 1-3/4 inch AC, no ACFC.

- Poorest performing test section, with no reduction in reflective cracking
- Ride remained as before overlaying
- Deflection increased with time
- Asphalt aged rapidly with viscosity well above 4.0 mega poise at 77°F

Test Section No. 7: 1-1/4 inch AC with 120/150 penetration LA Basin asphalt and 1/2 inch ACFC.

- Slightly less cracking than control sections
- Ride acceptable
- Deflection increased with time
- Asphalt aged rapidly to a value over 4.0 mega poise at 77°F

Test Section No. 8: 1-1/4 inch AC with 40/50 penetration LA asphalt and 1/2 inch ACFC.

- Did not reduce reflective cracking
- Ride acceptable
- Rut depth second deepest of all sections measured
- Deflection increased with time
- Asphalt viscosity above 4.0 mega poise value after construction and continued to age rapidly

Test Section No. 9: 1-1/4 inch AC 120/150 penetration 4-Corners asphalt and 1/2 inch ACFC.

- Did not reduce reflective cracking
- Ride more than acceptable
- Rut depth quite large
- Deflection increased with time
- Asphalt aged slowly, but increased above the 4.0 mega poise level

Test Section No. 10: 1-1/4 inch AC 200/300 penetration LA Basin asphalt, 1/2 inch ACFC.

- Prevented reflective cracks
- Smoothest ride
- Deflection increased with time
- Asphalt aging was moderate with viscosity remaining below the 4.0 mega poise level

Test Section No. 11: 1-1/4 inch open graded cold mix, emulsion treated AC, 1/2 inch ACFC.

- Slightly less cracking than control sections
- Poorest ride of all sections
- Rut depth not excessive
- Deflection increased with time
- Asphalt had high viscosity at placement and continued to age rapidly

Test Section No. 12: Petromat over old cracked AC, 1-1/4 inch AC, 1/2 inch ACFC.

- Slightly less cracking than control sections
- Ride very good
- Rut depth shallow
- Deflection changed little with time

Test Section No. 13: Fiberglass over old cracked AC, 1-1/4 inch AC, 1/2 inch ACFC.

- Prevented reflected cracks
- Ride very good
- Deflection changed little with time

Test Section No. 14: 1-1/4 inch AC overlay, Petroset flush, 1/2 inch ACFC.

- Cracking same as control section
- Ride fair
- Rutting average
- Deflection increased with time
- Performance very similar to control sections

Test Section No. 15: Petroset in cracks, 1-1/4 AC overlay, 1/2 inch ACFC.

- Slightly less cracking than control section
- Ride good
- Rut depth average. Similar to control sections
- Deflection increased with time

Test Section No. 16: Reclamite in cracks, 1-1/4 inch AC, 1/2 inch ACFC.

- Cracking similar to control section
- Ride and rut depth slightly worse than control section
- Deflection increased considerably with time

Test Section No. 17: Reclamite flush, 1-1/4 inch AC, 1/2 inch ACFC.

- Similar to Test Section No. 16 and control sections

Test Section No. 18A: Heater scarifying, reclamite flush, 1-1/4 inch AC, 1/2 inch ACFC.

- Prevented reflective cracks
- Ride good
- Deflection increased slightly with time

Test Section No. 18B: Same as Test Section No. 18A, except 3 inch overlay.

- Prevented reflective cracks
- Ride good
- Deflection increased slightly with time

Test Section No. 18C: Same as Test Section No. 18A, except constructed over a stripping aggregate in the old AC.

- Considerable potholing
- Deflection increased with time and were very high

Reflective Cracking Ranking

Table 16 presents a test section ranking with respect to each treatments ability to prevent or reduce reflection cracking. The percentage figures represent a computer count of reflected cracks per unit area (as of March, 1975) divided by the number of cracks in the original base prior to overlay.

Those test sections above the dashed line are considered to have significantly reduced reflective cracking.

Asphalt Concrete Finish Course (ACFC)

Based on project test results, ACFC's by themselves do not prevent cracking, but when placed over an overlay, they do tend to hide cracks. This hiding characteristic is due to the large internal structure (macro texture) of the ACFC.

Rideability

The roadway surface or rideability is influenced primarily by construction techniques and the materials used. Within this project, smooth riding sections contained petromat, fiberglass or low viscosity asphalts. In contrast, poor riding sections contained no ACFC or were blade laid.

Rutting

Generally, rutting was not excessive on any test section except when a asphalt rubber seal coat was used with no ACFC. This was probably due to the unintended application of 1.00 gal/yd^2 of asphalt rubber.

Deflection

After overlaying deflection readings were found to be lower. However, with time deflection increased, such that after approximately 12 months the 1-1/4 inch AC with 1/2 inch ACFC had increased to the previous deflection values (before overlay). After 37 months the 3 inch AC, 1/2 inch ACFC had increased to the previous deflection values. This roughly equates to about 12 months of deflection reduction per inch of overlay. No specific treatment claimed to reduce deflection, although, the asphalt rubber and asbestos sections did reduce deflection and maintained reduced deflection with time. An important observation did result from this study; that is, all test sections experienced dynaflect deflections ranging from 1 to 3 mils. This means that uncracked sections are preventing both shrinkage and fatigue cracks.

General Asphalt Properties

Generally it was found that basic asphalt properties influenced the reduction of reflective cracking more than any other property. During this project the 4.0 mega poise at 77°F viscosity (equivalent penetration about 45, absolute unaged viscosity of 3000 poises at 140°F) appears to be critical to crack initiation. The longer an asphalt can maintain a viscosity below 4.0 mega poise the less likely reflective cracks will form. Actual physical crack formation and intensity, however, is triggered by cold temperature. As such, once an asphalt reaches the 4.0 mega poise level, it is subject to cracking and will do so at such time the temperature becomes cold enough.

The above discussion refers primarily to asphalt in the AC mix. Other treatments are also influenced

TABLE 16

Test Section Rating

Treatment and Test Section (T.S.) Designation		Percent of Reflective Cracking Appearing by 1975
1-¼" AC Overlay and ½" ACFC		
Heater Scarification with Petroset	T.S. No. 2	3
Asphalt Rubber Under ACFC	T.S. No. 3 & 4	4
Fiberglass	T.S. No. 13	5
Heat Scarification with Reclamite	T.S. No. 18 A	6
200/300 penetration	T.S. No. 10	8
Petromat	T.S. No. 12	12
Petroset in cracks	T.S. No. 15	12
Asbestos	T.S. No. 5	13
120/150 penetration LA Basin	T.S. No. 7	14
Emulsion Treated AC	T.S. No. 11	14
Reclamite flush	T.S. No. 17	15
Petroset flush	T.S. No. 14	16
Control sections	———	17
120/150 penetration Four Corners	T.S. No. 9	18
Reclamite in cracks	T.S. No. 16	20
40/50 penetration LA Basin	T.S. No. 8	20
2" AC, No ACFC		
Rubberized asphalt seal coat	T.S. No. 1	19
2" AC no ACFC	T.S. No. 6	64

by asphalt properties. Heater scarification is a mechanical rearrangement of the crack pattern; yet even here, the asphalt viscosity is lowered by introducing reclamite or Petroset. The fiberglass section appeared to perform better than the Petromat section because more asphalt was used. Rubber asphalt also performed quite well due to low asphalt viscosity and the physical rubber properties.

From all this, it appears that the important consideration for all systems is to use the lowest viscosity asphalt commensurate with strength requirements, and to use it in such a way as to retard aging as much as possible.

Stripping – Original Pavement

Experience shows that the stripping of old pavement under an overlay can occur. This behavior, however, can probably be predicted by careful evaluation and consideration of the mineral aggregate source used in the original (old) pavement. Such stripping can be partially prevented by applying a dense overlay such as to prevent surface water from reaching the old AC.

Cost Considerations

Tradeoffs between initial cost and long term performance were found to be considerable. In three years of service, the cumulative cost per mile for maintaining the 1-1/4 inch AC plus 1/2 inch ACFC has been $8900, while the 3 inch AC plus 1/2 inch ACFC was $2000, and the 1-1/4 inch AC plus 1/2 inch ACFC with stripping of old AC was $15,000.

Put another way, the cost/square yard has increased as indicated in Table 17 below:

TABLE 17
Initial vs. Long Term Costs

Treatment	% Reflected Cracking in 3 Years	Initial Cost/Yd^2	3 Year Cumulative Maintenance Cost/Yd^2	Total
2" AC, No ACFC	64%	$1.58	$.93	$2.51
¼" AC Plus ½" Open Graded ACFC	17%	1.56	.63	2.19
1¼" AC Plus ½" Open Graded ACFC Plus Treatment 200/300 Pen. Asphalt	8%	1.56	.12	1.68
Heater Scarification Plus Reclamite	6%	1.91	.08	1.99
Fiberglass	5%	2.45	.06	2.51
Asphalt Rubber Under ACFC	4%	2.32	.04	2.36
Heater Scarification Plus Petroset	3%	1.91	.04	1.95

Recommendations

The Minnetonka-East program, in conjunction with federal NEEP Project Number 10, was initiated in an attempt to better understand the mechanisms, treatments, and methods necessary for the prevention of reflective cracking in the overlays when placed over severely cracked bituminous pavements.

This report represents the culmination of over four years of careful planning, construction, and objective data analysis, resulting in a myriad of meaningful information which should be of value to federal, state, and local agencies concerned with not only the restoration of existing roadways, but also new highway construction.

The following recommendations refer to overlays, but in particular, thin overlays (4 inches or less) placed over existing badly cracked, rutted, or otherwise distorted bituminous pavements. Overlaying can also be for reasons of improved skid resistance or rideability, to name a few. The reader should keep in mind, however, that no one treatment is a cure-all for all roadway conditions. Rather, the reported (recommended) crack preventing treatments should be integrated into an overlay design, carefully tailored to the nature of the distress.

1. Five treatments were found to have significantly reduced reflective cracking. They are:
   - Heater scarification with Petroset.
   - Asphalt rubber membrane seal coat under ACFC.
   - Fiberglass membrane.
   - Heater scarification with reclamite.
   - 200/300 Penetration Asphalt
2. One or more (in combination) of the above treatments should be used for all thin overlays (4 inches or less) placed over badly cracked pavements. Considerations are as follows:
   a). Scarification should be to a depth of 3/4 inches. This top 3/4 inches of old AC pavement asphalt should be pretested for viscosity and the amount of reclamite or other rejuvenating agent required to an equivalent 200/300 penetration (AR 1000 or less). These test results should be determined and called for in the specifications.
   b) The lowest possible viscosity asphalt with the slowest aging characteristics should be used in the AC overlay. At present, such an asphalt would be acceptable for regions below the freezing index line, Figure 6. Unfortunately, as of this report, an asphalt grade of suitably low viscosity for freezing index regions is not available. Such a grade, however, would most closely resemble an AC 2.5 asphalt and efforts should be made to acquire such an asphalt. In addition, investigative work in the area of reducing aging through the use of additives in the asphalt mixture should be continued.
   Please note that low viscosity asphalt refers to the AC. Higher viscosity asphalts should be used in the ACFC.
   c) 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 and to carry construction equipment and temporary traffic.
   d) Fiberglass membrane material can be somewhat cumbersome to use during construction, but could possibly be utilized during maintenance as a pre-overlay treatment on selected small areas.

3. Existing roadways which are being considered for overlay should be carefully investigated for possible stripping tendencies. Should stripping appear likely, efforts should be made to either:
   a) Give no structural value to the existing AC. Instead, represent it as an unbound base and design the overlay accordingly. In this way,

the overlay will be much thicker. Also, densify the overlay to at least 92 percent of maximum theoretical density.

b) Reconstruct the existing surface. Such an effort could involve recycling the old AC, followed by a suitable additive treatment (anti-stripping agent, lime or cement). An alternative would be complete removal of the existing surface and replacement with new AC.

4. Open texture surfaces should be placed on top of dense graded overlays. In this way, not only will good skid resistance be achieved but a large percentage of reflective cracks will be hidden. For high speed highways an open graded ACFC is recommended.

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Performance Testing	Chris Cornel, Materials Field Engineer-Design Elmer Green, Research Chemist
Maintenance	Rex Wolfe, Assistant District Engineer, District 4 Maintenance Staff District 4
General	Advice and comments from: Grant J. Allen, Engineer of Materials Rowan J. Peters, Assistant Engineer of Materials, Research Branch Gene Morris, Research Engineer

Appendix A
Supporting Data Tables

TABLE 1A
Material Survey – Average Index Properties*, Minnetonka-East, April 1, 1969

Eastbound Interstate 40

					Grading					
Station	**Depth*****	**Desc.**	**LL**	**PI**	**-200**	**-40**	**-8**	**-4**	**-¼**	**-¾**
205 - 495	6″ to 19″	SM		NP**	8	66	96	98	98	99
205 - 495	10″ to 24″	Borrow	21	4	30	81	97	98	98	100
505 - 695	4″ to 10″	AB		NP	9	32	69	75	79	100
505 - 695	10″ to 22″	SM		NP	9	79	96	97	97	99
505 - 695	15″ to 30″	Sub Seal		NP	24	81	98	99	99	99

Westbound Interstate 40

					Grading					
Station	**Depth**	**Desc.**	**LL**	**PI**	**-200**	**-40**	**-8**	**-4**	**-¼**	**-¾**
205 - 495	6″ to 19″	SM		NP	8	67	97	100	100	100
205 - 495	10″ to 24″	Borrow	22	5	38	88	100	100	100	100
500 - 695	4″ to 10″	AB		NP	10	33	70	76	80	100
500 - 695	10″ to 22″	SM		NP	9	81	97	98	98	99
500 - 695	15″ to 30″	Sub Seal		NP	23	84	97	98	98	99

* Test results based on average of 20 to 30 tests.
** NP is non-plastic.
*** Depths varied as a function of construction.

TABLE 2A
Average* Rut Depths in Wheel Paths, Minnetonka-East, February 1970, Values in Inches

	Travel Lane		Passing Lane	
Station	**Right** 10 Feet**	**Right 4 Feet**	**Left 4 Feet**	**Left 10 Feet**
Eastbound				
210 - 500	.59	.37	.32	.09
500 - 692	.47	.74	.34	.32
Westbound				
210 - 500	.60	.44	.50	.17
500 - 685	.61	.80	.44	.33

*Values based on 20 to 30 tests at 1000 foot intervals.
**Location of test.

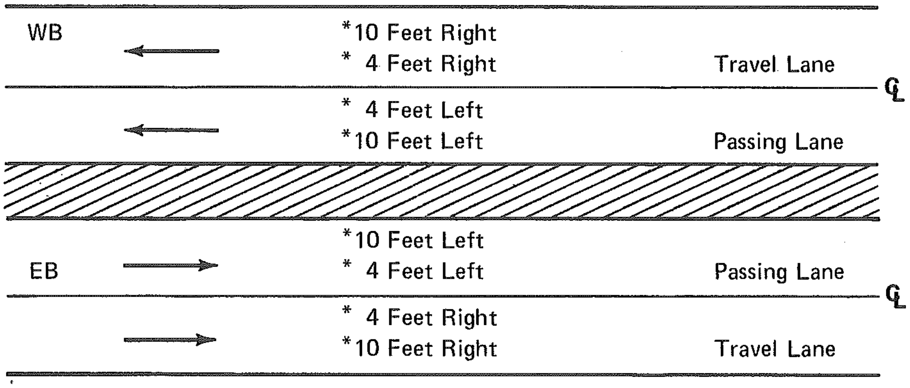

TABLE 3A
Benkleman Beam Average Deflections*, Minnetonka-East, October 30, 1969, Air Temperature 48 – 88°F (Deflections in Inches)

	Travel Lane	
Station	**4 Feet Right**	**10 Feet Right**
Eastbound		
210 - 260	.0235	.0203
270 - 365	.0408	.0429
370 - 500	.0502	.0529
510 - 685	.0292	.0286
Westbound		
209 - 265	.0238	.0242
270 - 365	.0400	.0415
370 - 500	.0425	.0457
500 - 685	.0247	.0243

*Averages based on 10 to 30 tests per station section.

TABLE 4A (Part 1)
Minnetonka-East, Cracking Interpretation, % Area Cracked

	% Cracking Before Overlay	% Cracking After Overlay			
East Bound Location	**1971**	**1972**	**1973**	**1974**	**1975**
229+75 - 230 R	9.6%	0	0	0	0
254+75 - 255 R	7.3	0	0	0	0
266+75 - 267 W	15.0	0	0	0	2.0
283+25 - 50 R	11.0	1.0	1.6	.8	4.9
284+50 - 75 W	10.8	1.9	2.1	2.1	4.6
285+00 - 25 R	1.7	0	0	0	0
292+50 - 75 R	15.1	0	0	0	1.2
293+50 - 75 W	12.9	0	0	0	0
295+75 - 296 W	11.8	1.8	1.4	1.6	3.8
299+75 - 300 R	11.7	0	0	0	0
557+75 - 558 R	2.0	0	0	0	0
558+00 - 25 R	10.2	0	0	0	0
604+75 - 605 R	16.7	0	0	1.0	1.0
639+75 - 640 R	24.0	0	0	0	0
649+75 - 650 R	15.5	0	0	1.4	2.0
West Bound Location					
239+75 - 240 R	8.1		0	0	1.7
271+75 - 272 R	8.4		1.2	1.8	3.1
329+75 - 330 R	7.1		0	0	1.6
401+75 - 402 R	13.1		0	0	0
499+75 - 500 R	26.3		0	0	1.3
599+75 - 600 R	13.0		0	.5	.5

W = Worse cracking location within section as determined by eye.
R = Random location.

TABLE 4A (Part 2)
Cracking Interpretation, % Area Cracked, Minnetonka-East

East Bound Location	% Cracking Before Overlay		% Cracking After Overlay		
	1971	1972	1973	1974	1975
302+75 - 303 W	11.6	16.0	1.9	4.1	4.2
309+25 - 50 R	15.5	21.4	0	0	2.6
310+25 - 50 R	19.1	30.2	0	0	2.4
317+75 - 318 R	13.8	21.8	0	0	0
319+00 - 25 W	12.2	18.3	0	0	1.9
320+50 - 75 W	12.3	25.5	0	0	1.0
322+75 - 323 R	17.7	25.3	0	0	3.0
325+25 - 50 W	14.8	32.0	0	.8	1.9
326+50 - 75 R	12.6	27.2	0	0	0
334+00 - 25 R	12.0	11.1	0	0	0
335+00 - 25 R	9.4	12.1	0	0	2.0
337+00 - 25 W	12.1	32.7	0	0	3.1
341+50 - 75 R	9.5	10.4	0	0	1.4
346+00 - 25 W	16.1	34.1	0	0	1.1
349+50 - 75 R	10.0	19.4	0	0	0
353+50 - 75 R	7.9	8.5	0	1.0	3.3
358+75 - 359 R	9.8	11.0	0	3.8	10.0
362+50 - 75 R	9.5	9.0	0	3.2	10.7
368+00 - 25 R	19.6	15.6	0	5.1	7.7
368+75 - 369 W	32.5	31.8	0	5.6	7.1
371+00 - 25 W	30.3	43.5	1.0	2.0	7.1
372+00 - 25 R	18.2	32.2	0	.4	4.1
375+00 - 25 R	28.2	24.5	0	0	3.4
381+75 - 381 W	35.7	49.2	0	0	2.5
383+25 - 50 R	40.7	54.2	0	0	3.6
386+75 - 387 R	23.1	31.1	.5	2.6	7.0
392+50 - 75 W	42.0	64.1	3.6	16.5	15.8
394+75 - 395 R	31.7	43.0	0	0	5.1

TABLE 4A (Part 2)
Cracking Interpretation, % Area Cracked, Minnetonka-East

East Bound Location	% Cracking Before Overlay		% Cracking After Overlay		
	1971	1972	1973	1974	1975
397+50 - 75 W	28.5	35.0	1.7	7.4	8.7
399+25 - 50 R	15.2	14.7	0	1.2	2.9
404+00 - 25 R	12.8	11.7	0	0	1.2
407+75 - 408 R	26.5	28.5	0	0	1.9
409+00 - 25 W	21.1	43.0	0	0	3.6
412+75 - 413 R	24.8	20.3	0	0	.4
416+00 - 25 R	12.3	10.0	0	0	1.0
410+00 - 25 W	25.5	25.7	0	0	2.8
420+50 - 75 W	25.2	34.1	0	1.6	4.3
421+75 - 422 R	19.5	20.0	0	.6	2.9
426+00 - 25 W	44.0	46.1	0	0	1.1
427+25 - 50 R	26.8	34.1	2.0	8.3	9.6
435+00 - 25 W	43.9	44.4	0	0	4.2
433+75 - 444 R	18.4	19.0	0	1.0	5.4
437+75 - 438 R	30.0	32.3	0	0	4.8
440+50 - 75 W	30.2	29.9	0	0	2.4
440+75 - 441 R		30.4	0	.4	1.6
441+75 - 442 R		11.1	0	0	0
443+75 - 444 R		30.5	0	0	1.7
448+25 - 50 W	34.4	39.4	2.2	3.5	4.9
449+50 - 75 R	23.1	23.7	2.9	3.6	8.7
452+00 - 25 W	32.4	31.0	1.8	3.7	6.4
453+50 - 75 R	44.0	48.9	1.2	4.2	7.0
455+75 - 456 R	32.7	38.1	1.9	2.8	5.1
460+25 - 50 R	25.2	27.0	0	0	3.8
465+75 - 466 W	37.5	41.5	0	2.9	4.2
467+75 - 468 R	30.6	40.9	0	.8	5.1
470+25 - 50 R	14.3	16.0	0	0	2.5
473+00 - 25 W	20.0	22.0	0	0	3.0
478+75 - 479 W	23.2	31.7	0	0	2.0
479+50 - 75 R	22.2	20.5	1.8	5.6	6.1
483+25 - 50 R	15.5	26.1	2.6	4.3	5.3
487+75 - 488 R	12.8	15.8	0	0	.9
490+75 - 491 W	16.1	23.7	0	1.8	4.8
491+00 - 25 R	20.4	17.3	0	0	3.5
498+00 - 25 R	14.0	0	2.0	4.9	5.5
499+00 - 25 R	13.0	0	0	0	.8
499+25 - 50 R	12.8	0	0	0	.5

TABLE 5A
Rideability Values, Mays-Ride Meter, I 40 Eastbound

	Roughness (Inches)							
Location (EB)	4/11/72*	7/11/72**	2/26/73***	7/31/73	10/10/73	2/21/74	5/16/74	5/21/75
TS # 2, Sta. 285-295			.80	1.15	1.00	.75	.90	1.82
CS, Sta. 295-300			.45	.70	.55	.45	.65	.74
TS # 1, Sta. 300-310			3.25	3.90	2.95	2.80	2.70	3.22
TS # 3, Sta. 310-320			1.75	2.35	1.95	2.70	1.75	2.56
CS, Sta. 320-325			.40	.55	.35	.55	.75	1.24
TS # 4, Sta. 325-335			1.55	2.40	2.55	2.55	2.40	2.72
TS # 5, Sta. 335-345	2.95	1.00	1.45	1.50	1.50	1.15	1.40	1.82
CS, Sta. 345-350	2.00	1.10	1.00	1.15	1.05	1.15	1.20	1.24
TS # 6, Sta. 350-370	5.85	1.60	3.95	4.75	4.20	4.00	4.95	6.76
TS # 7, Sta. 370-380	3.00	.65	1.10	1.60	1.10	1.00	1.35	
CS, Sta. 380-385	1.90	.35	.60	.75	.75	.50	.70	.50
TS # 8, Sta. 385-395	3.00	.60	.95	1.40	1.10	1.65	2.20	2.56
TS # 9, Sta. 395-405	3.15	.30	.90	1.35	1.05	1.20	1.40	1.57
CS, Sta. 405-410	1.95	.25	.50	.70	.45	.45	.55	.66
TS #10, Sta. 410-420	2.80	.50	1.00	1.10	.90	.90	1.05	.58
TS #11, Sta. 420-430	3.40	1.30	2.20	3.40	3.10	2.80	2.90	3.38
CS, Sta. 430-435	2.15	.35	.60	.90	.80	.75	1.00	2.56
TS #12, Sta. 435-440	2.20	.45	.40	.65	.55	.45	.40	.58
TS #13, Sta. 440-445	2.10	.50	.55	.75	.50	.55	.60	.91
CS, Sta. 445-450	2.10	.55	1.15	1.35	1.10	1.35	1.55	1.65
TS #14, Sta. 450-460	4.05	.65	1.65	2.20	1.85	1.90	2.20	2.39
TS #15, Sta. 460-470	4.00	.25	1.00	1.60	1.75	1.45	1.65	2.97
CS, Sta. 470-475	1.95	.25	.60	.75	.85	.85	.80	
TS #16, Sta. 475-485	3.05	.45	1.50	1.55	1.70	1.50	1.90	1.98
TS #17, Sta. 485-495	4.05	.45	.75	1.15	1.15	1.15	1.50	1.82
Total Roughness (In)	55.65	11.55	30.05	39.65	34.30	34.55	38.45	46.23
Total Ride Index	3.34	3.96	3.80	3.70	3.75	3.75	3.71	3.63

* Note: This survey was taken in a 1972 Chevrolet station wagon before the new overlay.

** Note: This survey was taken in the 1972 Chevrolet station wagon after the new overlay.

*** Note: This survey and, all subsequent ones, were taken in a 1973 American Motors Matador.

TABLE 5A (Continued)
Rideability Values, Mays-Ride Meter, I 40 Westbound

I 40 Westbound

Date	Roughness (Inches)						
	MP 260-261	MP 261-262	MP 262-263	MP 263-264	MP 264-265	Total Roughness (Inches)	Total Ride Index
4-11-72*							
8-31-72**	1.85	1.00	1.35	1.80	4.30	10.30	4.03
2-26-73***	3.80	4.00	4.10	4.65	6.85	23.40	3.92
7-31-73	4.50	4.10	4.10	4.85	7.15	24.70	3.91
2-21-74	4.30	4.60	3.95	4.45	7.15	24.45	3.91
5-16-74	5.15	5.40	4.40	4.70	6.90	26.55	3.87
5-21-75	3.87	2.64	3.14	4.04	7.34	21.03	3.94

* Note: No data was taken prior to overlay.

** Note: This survey was obtained in a 1972 Chevrolet station wagon after the overlay.

*** Note: This survey, and all subsequent ones, were taken in a 1973 AMC Matador.

TABLE 6A
Percent of Original Roughness, Eastbound

Location	7/11/72	2/26/73	7/31/73	10/10/73	2/21/74	5/16/74	5/21/75
TS # 2 - 285 - 295		27	38	33	25	30	61
CS - 295 - 300		23	35	28	23	33	37
TS # 1 - 300 - 310		108	130	98	93	90	107
TS # 3 - 310 - 320		58	78	65	90	58	85
CS - 320 - 325		20	28	18	28	38	62
TS # 4 - 325 - 335		52	80	85	85	80	91
TS # 5 - 335 - 345	34	49	51	51	39	47	62
CS - 345 - 350	55	50	58	53	58	60	62
TS # 6 - 350 - 370	27	68	81	72	68	85	91
TS # 7 - 370 - 380	22	37	53	37	33	45	48
CS - 380 - 385	18	32	39	39	26	37	26
TS # 8 - 385 - 395	20	32	47	37	55	73	85
TS # 9 - 395 - 405	10	29	43	33	38	44	50
CS - 405 - 410	13	26	36	23	23	28	34
TS #10 - 410 - 420	18	36	39	32	32	38	21
TS #11 - 420 - 430	38	65	100	91	82	85	99
CS - 430 - 435	16	28	42	37	35	47	119
TS #12 - 435 - 440	20	18	30	25	20	18	26
TS #13 - 440 - 445	24	26	36	24	26	29	43
CS - 445 - 450	26	55	64	52	64	74	79
TS #14 - 450 - 460	16	41	54	46	47	54	59
TS #15 - 460 - 470	6	25	40	44	36	41	50
CS - 470 - 475	13	31	38	44	44	41	50
TS #16 - 475 - 485	15	49	51	56	49	62	65
TS #17 - 485 - 495	11	19	28	28	28	37	45

Note: $\% \text{ of Original Roughness} = \dfrac{\text{New Roughness (Date)}}{\text{Original Roughness (4/11/72)}}$

TABLE 7A
Deflection Test Results

Date Of Test And Air Temperature	Average Deflection Mils	Values Based On Percent Change In Individual Deflections						
		(N) Number Of Tests	(X) Average Change	Standard Deviation	High Change	Low Change	# Above Original	# Below Original
East Bound								
June, 71 100°F	1.45	79	100					
Aug, 71 80°F	1.37	63	89	12	131	53	9	54
June, 72 76°F	1.22	78	84	17	184	48	7	71
Oct, 72 54°F	1.23	79	85	17	141	52	12	67
May, 73 74°F	1.89	79	130	31	257	70	74	6
Jan, 74 46°F	2.04	78	141	47	312	72	70	8
May, 75 69°F	1.74	78	120	34	271	60	60	18
June, 75 69°F	1.74	78	120	34	290	52	64	14
West Bound								
June, 71 100°F	1.13	90	100					
Aug, 71 80°F								
June, 72 76°F								
Oct, 72 54°F	.98	87	87	23	154	51	23	64
May, 73 74°F	1.04	87	92	15	137	66	33	54
Jan, 74 46°F	1.24	89	110	34	196	47	48	41
May, 74 69°F	1.39	89	123	40	214	46	58	31
June, 75 69°F	1.42	88	126	40	222	54	59	29

DEPARTMENT OF TRANSPORTATION STATE OF ARIZONA

TABLE 8A
Skid Resistance Values – Mu Meter, Test Performed on First 500 Feet at Each Milepost

Station	Milepost	Skid Value				
		8/71	11/72	7/73	8/74	6/75
East Bound						
275-280	260	55	74	66	80	72
328-333	261	60	73	70	73	52
380-385	262	40	76	70	86	79
433-438	263	50	78	68	84	76
485-490	264	70	74	70	87	74
539-544	265	55	83	72	95	84
592-597	266	40	81	74	81	82
644-649	267	30	79	75	63	80
West Bound						
275-280	260	63	75	No Test	86	77
328-333	261	63	79		84	68
380-385	262	62	76		86	74
433-438	263	62	75		80	64
485-490	264	56	77		84	74
539-544	265	42	80		86	84
592-597	266	47	76		82	80
644-649	267	51	74		83	79

TABLE 9A
Micro Viscosity Values, Viscosities Measured at 77°F, Displayed in Mega-Poises

Asphalt Grades	Before Laydown May 72	Years After Laydown			
		Sept. 72	1973	1974	1975
40/50 Pen L.A. T.S. 8	3.49	7.78	53.90	87.50	69.20
60/70 Pen L.A. T.S. 18	1.53	6.04	–	–	25.00
85/100 Pen L.A. T.S. 6	.88	6.69	10.20	18.20	21.40
120/150 Pen L.A. T.S. 7	.43	.57	–	4.64	5.60
120/150 Pen 4 C. T.S. 9	.52	1.61	4.20	5.24	6.10
200/300 Pen L.A. T.S. 10	.13	.97	1.61	1.59	2.90
Asphalt Rubber					
Seal Coat No ACFC T.S. 1	.43*	–	–	.88	2.16
Seal Coat with ACFC T.S. 3 & 4	.43*	–	–	.97	1.10
Heater Scarification	After Heating	After Flush			
with Petroset T.S. 2	60.00	1.42	5.92	9.91	28.00
with Reclamite T.S. 18	60.00	.34	5.63	20.80	30.30
Other					
Asbestos T.S. 5	1.53	–	–	5.71	4.53
Emulsion Treated Base T.S. 11	3.70	–	–	14.60	19.70
AC with no ACFC	.88	–	–	22.70	21.40
AC with ACFC	.88	5.30	–	18.20	21.60
ACFC	.88	5.60	17.40	18.20	27.70
Old AC	35.90	–	275.0	–	3170.

*Sample taken before mixing with rubber.

TABLE 10A
Absolute Viscosity in Poises, Test Performed at 140°F

	Before Overlay May, 1972	Years After Overlay			
Asphalt Grades		**Sept. 1972**	**1973**	**1974**	**1975**
40/50 Pen L.A. T.S. 8	2492	6622	37,732	44,782	38,269
60/70 Pen L.A. T.S. 5	1252	4427	–	–	36,101
85/100 Pen L.A. T.S. 6	1018	5443	8422	14,272	35,510
120/150 Pen L.A. T.S. 7	542	822	–	3627	3962
120/150 Pen 4 C T.S. 9	669	1431	3416	3836	4351
200/300 Pen L.A. T.S. 10	258	1006	1410	1423	2329
Asphalt Rubber					
Seal Coat no ACFC T.S. 1	542*	–	–	1221	2041
Seal Coat with ACFC T.S. 3 & 4	542*	–	–	1072	1923
Heater Scarification	After Heating	After Flush			
with Petroset T.S. 2	251,584	2787	4622	8116	36,253
with Reclamite T.S. 18	251,584	1678	4736	35,230	37,160
Other					
Asbestos	1252	–	–	3888	3763
Emulsion Treated Bas T.S. 11	3426	–	–	20,160	36,352
AC with no ACFC T.S. 6	1018	–	–	34,223	36,426
AC with ACFC	1018	4071	–	33,162	36,213
ACFC	1018	4432	35,261	31,341	38 175
Old AC	–	–	–	–	–

*Sample taken before mixing with rubber.

TABLE 11A
Penetration Values for Various Asphalt Operations

	Before Overlay	Years After Overlay			
Asphalt Grades	**May, 1972**	**Sept, 1972**	**1973**	**1974**	**1975**
40/50 Pen L.A. T.S. 8	48	34	14	11	12
60/70 Pen L.A. T.S. 5	71	38	–	–	20
85/100 Pen L.A. T.S. 6	103	36	30	23	21
120/150 Pen L.A. T.S. 7	144	115	–	43	39
120/150 Pen 4 C. T.S. 9	127	70	45	41	38
200/300 Pen L.A. T.S. 10	242	89	70	70	54
Asphalt Rubber					
Seal Coat No. ACFC T.S. 1	144*	–	–	92	61
Seal Coat with ACFC T.S. 3 & 4	144*	–	–	89	66
Heater Scarification	After Heating	After Flush			
with Petroset T.S. 2	14	105	38	30	19
with Reclamite T.S. 18	14	144	39	22	18
Other					
Asbestos T.S. 5	71	–	–	39	44
Emulstion Treated Base T.S. 11	48	–	–	25	22
AC with no ACFC T.S. 6	103	–	–	21	21
AC with ACFC	103	41	–	23	21
ACFC	103	38	22	23	20
Old AC	18	–	6	–	2

*Sample taken before mixing with rubber.

TABLE 12A
Rapid Rostler – Percent Asphaltenes (A) For Various Operations

Rapid Rostler:
A = Asphaltenes
$N+A_1$ = Nitrogen Bases + 1st Acidaffins
A_2+P = 2nd Acidaffins + Parafins
} = 100%

Asphalt Grades	Before Overlay May, 1972	Years After Overlay			
		Sept, 1972	1973	1974	1975
40/50 Pen. L.A. T.S. 8	30.1	33.6	30.2	32.7	29.6
60/70 Pen. L.A. T.S. 5	20.5	30.4	–	–	29.7
85/100 Pen. L.A. T.S. 6	26.2	36.4	29.4	–	35.5
120/150 Pen. L.A. T.S. 7	28.1	32.5	–	26.3	28.4
120/150 Pen. 4 C. T.S. 9	13.5	15.5	15.4	15.0	16.1
200/300 Pen. L.A. T.S. 10	20.0	26.4	26.4	26.9	27.3
Asphalt Rubber					
Seal Coat no ACFC T.S. 1	28.1	–	–	25.9	29.5
Seal Coat with ACFC T.S. 3 & 4	28.1	–	–	27.2	24.9
Heater Scarification	After Heating	After Flush	April 1972	1974	1975
with Petroset T.S. 2	43.4	32.4	23.1	30.0	33.5
with Reclamite T.S. 18	43.4	28.7	24.2	32.3	32.1
Other					
Asbestos T.S. 5	20.5	–	–	30.8	21.2
Emulsion Treated Base T.S. 11	–	–	–	30.8	32.5
AC with no ACFC T.S. 6	26.2	–	29.4	35.3	35.5
AC with ACFC	26.2	–	29.4	31.6	28.9
ACFC	26.2	–	32.5	31.6	–
Old AC	36.6	–	43.0	–	57.1

*Sample taken before mixing with rubber.

TABLE 13A
Rapid Rostler – Percent Nitrogen Bases (N) Plus 1st Acidaffins (A1)

Asphalt Grades	Before Overlay May, 1972	Years After Overlay Sept, 1972	1973	1974	1975
40/50 Pen L.A. T.S. 8	34.6	31.0	43.0	43.8	42.4
60/70 Pen. L.A. T.S. 5	47.1	40.8	–	–	39.9
85/100 Pen. L.A. T.S. 6	30.5	23.0	36.0	–	25.8
120/150 Pen. L.A. T.S. 7	35.2	32.5	–	43.1	40.8
120/150 Pen. 4 C. T.S. 9	39.3	27.6	44.1	48.2	45.3
200/300 Pen. L.A. T.S. 10	37.1	35.4	40.7	42.9	38.9
Asphalt Rubber					
Seal Coat no ACFC T.S. 1	35.2*	–	–	40.9	36.3
Seal Coat with ACFC T.S. 3 & 4	35.2	–	–	36.4	37.3
Heater Scarification	After Heating	After Flush	April 1972	1974	1975
with Petroset T.S. 2	31.00	33.9	47.2	38.8	35.2
with Reclamite T.S. 18	31.00	32.7	44.5	35.6	35.2
Other					
Asbestos T.S. 5	47.1	–	–	41.4	45.0
Emulstion Treated Base T.S. 11			–	45.4	41.5
AC with no ACFC T.S. 6	30.5	–	36.0	26.7	25.8
AC with ACFC	30.5	–	36.0	40.4	38.9
ACFC	30.5	–	36.0	40.4	–
Old AC	34.3	–	31.7	–	24.9

*Sample taken before mixing with rubber.

TABLE 14A
Rapid Rostler – Percent 2nd Acidaffins Plus Paraffins

Asphalt Grades	Before Overlay May, 1972	Years After Overlay			
		Sept, 1972	1973	1974	1975
40/50 Pen. L.A. T.S. 8	35.3	35.4	26.8	23.5	28.0
60/70 Pen. L.A. T.S. 5	32.4	28.8	–	–	30.5
85/100 Pen. L.A. T.S. 6	43.4	40.6	34.6	–	38.6
120/150 Pen. L.A. T.S. 7	36.7	31.6	–	30.6	30.8
120/150 Pen. 4 C. T.S. 9	47.3	56.9	40.5	36.8	38.6
200/300 Pen. L.A. T.S. 10	42.9	38.3	32.9	30.2	33.7
Asphalt Rubber					
Seal Coat no ACFC T.S. 1	36.7*	–	–	33.2	34.2
Seal Coat with ACFC T.S. 3 & 4	36.7*	–	–	36.4	37.9
Heater Scarification	After Heating	After Flush	April 1972	1974	1975
with Petroset T.S. 2	25.6	33.7	29.7	31.2	31.2
with Reclamite T.S. 18	25.6	38.6	31.3	32.0	32.7
Other					
Asbestos	32.4	–	–	27.9	33.8
Emulsion Treated Base T.S. 11	–	–	–	23.9	26.0
AC with no ACFC T.S. 6	43.4	–	34.6	38.1	38.6
AC with ACFC	43.4	–	34.6	28.0	32.2
ACFC	43.4	–	34.6	28.0	–
Old AC	29.1	–	25.3	–	18.1

*Sample taken before mixing with rubber.

TABLE 15A
AC Vanadium Content

	Vanadium in Parts Per Million (ppm) Test Performed in 1975	Aging Index
40/50 Pen. L.A. T.S. 8	98	19.8
60/70 Pen. L.A. T.S. 18	145	16.3
85/100 Pen. L.A. T.S. 6	130	24.3
120/150 Pen. L.A. T.S. 7	95	13.0
120/150 Pen. 4 C. T.S. 9	18	11.7
200/300 Pen. L.A. T.S. 10	95	22.3
Rubberized Seal Coat T.S. 1	120	
Rubberized Seal with ACFC T.S. 3	105	
Heater Scarification		
with Petroset T.S. 2	150	
with Reclamite T.S. 18	138	
Emulsion Treated Base	198	
AC with ACFC	150	
Old AC	175	

*$\frac{\text{1975 Micro-Viscosity @77}^{\circ}\text{F}}{\text{Original Unaged Micro-Viscosity @77}^{\circ}\text{F}}$

TABLE 16A
AC Aging vs. Temperature For Various Grades of Asphalt

	Viscosity in Mega Poise					
	Sept 1972	March 1975	Sept 1972	March 1975	Sept 1972	March 1975
Temperature	40/50 Pen		60/70 Pen		85/100 Pen	
60°F	74.2	422.0	43.1	No Test	24.1	91.0
77°F	7.8	62.9	6.0		6.7	21.4
95°F	1.1	4.9	.64		.85	4.9
140°F	.006	.038	.0041		.004	.036
	120/150 Pen LA		120/150 Pen 4 C		200/300 Pen	
60°F	6.4	53.7	12.9	79.7	6.2	32.6
77°F	.57	5.6	1.6	6.1	.97	2.9
95°F	.054	.42	.13	.50	.028	.28
140°F	.0009	.0040	.0014	.0044	.0012	.0023

TABLE 17A
Aging vs. Time To Critical Micro-Viscosity

Treatment	Months
40/50 Pen. L.A.	.5
60/70 Pen. L.A.	3.0
85/100 Pen. L.A.	3.0
120/150 Pen. 4 Corners	11.5
120/150 Pen. L.A.	20.0
200/300 Pen. L.A.	40.0
Asphalt Rubber	
Seal Coat no ACFC	44.0
Seal Coat with ACFC	150.0
Heater Scarification	
With Petroset	5.0
With Reclamite	6.0

TABLE 18A
Asphalt Grades

	Pen @ 77° F	Tests Absolute Viscosity 140°F		Grades**		
	Unaged	Unaged	Aged*	Pen	AR	AC
40/50 Pen. L.A.	48	2492	6358	40/50	8000	20**
60/70 Pen. L.A.	71	1252	2672	60/70**	2000**	10**
85/100 Pen. L.A.	103	1018	2669	85/100**	2000**	10
120/150 Pen. L.A.	144	542	1261	120/150	1000	5**
120/150 Pen. 4 Corners	127	669	1175	120/150	1000	5**
200/300 Pen. L.A.	242	258	579	200/300	1000***	2.5

* Tests performed with RTFO apparatus; RTFC equipment not yet invented at time of test.
** Asphalts placed in nearest grade. Degree of difference from spec could warrant a penalty situation.
*** No AR grade at present exists. This material would be placed under penalty in Arizona.

TABLE 19A
Penetration and Viscosity Before and After RTFC

Year	Viscosity @140°F Average Values			Penetration @ 70°F Average Values		
	N	Before RTFO or C	After 75 Min. RTFO or C	N	Before RTFO or C	After 75 Min. RTFO or C
	AR-4000 or 60/70 Pen.			60/70 Pen. or AR-4000		
1969	19	1954	4593	19	65	41
1970	46	1898	3811	46	64	41
1971	41	1615	3530	41	64	42
1972	39	1619	3634	39	67	42
1973	36	1663	3437	36	66	43
1974	56	1557	3612	56	66	41
	AR-2000 or 85/100 Pen.			85/100 Pen. or AR-2000		
1969	21	1104	2389	21	92	55
1970	47	991	2069	47	90	55
1971	25	948	2389	25	93	56
1972	43	967	2072	43	96	60
1973	42	1076	1832	42	93	57
1974	39	943	1868	39	94	59

TABLE 20A
Asphalt Penetration Index

	Pen @ 77°F	Kinematic Viscosity @ 275°F	Penetration Index	Temp. Ring and Ball °C
40/50 Pen. L.A.	48	340	-1.3	49
60/70 Pen. L.A.	71	260	-1.3	44
85/100 Pen. L.A.	103	210	-1.3	43
120/150 Pen. L.A.	144	170	-1.4	40
120/150 Pen 4 C.	127	160	-1.5	41
200/300 Pen. L.A.	242	120	-1.2	35

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TABLE 21A
Maintenance Costs – From July 7, 1972 to June 30, 1975

Date	Location and Direction	Work Description	Total Cost* ($)
11/30/72	Sta. 208-692 EB	Patch broken pavement	407
4/ 4/73	208-692 EB	Hand patch potholes	149
4/ 6/73	208-692 WB	Sealing cracks	377
4/ 9/73	208-692 WB	Sealing cracks	377
4/10/73	208-692 WB	Sealing cracks	355
4/11/73	208-692 EB	Sealing cracks, patch potholes	431
6/14/73	380-644 EB	Surface/base replacement	440
6/19/73 6/21/73	208-692 EB & WB	Flush Coat SS-1h Emulsion	10,622
7/ 9/73	538-692 EB	Surface/base replacement	456
7/30/73	591-622 EB	Surface/base replacement	921
7/31/73	591-692 EB	Surface/base replacement	586
8/ 1/73	591-692 EB	Surface/base replacement	760
8/ 2/73	538-692 EB	Surface/base replacement	815
9/ 5/73	591-692 EB	Surface/base replacement	687
9/ 6/73	591-692 EB	Surface/base replacement	485
9/19/73	538-692 EB	Spot seal patching	789
1/30/74 1/31/74	591-692 EB	Patch potholes	582
4/22/74	591-692 EB	Surf. Prep. for seal coat	537
8/ 9/74	538-692 EB	Patch broken pavement	403
8/12/74	538-692 EB & WB	Hand patch potholes	350
8/14/74	538-692 WB	Patch broken pavement	1,553
8/15/74	538-692 WB	Patch broken pavement	1,386
8/16-18/74	528-692 EB & WB	Rubberized seal coat	70,589
8/19-23/74	528-692 EB & WB	Sand bleeding seal coat	866
9/27/74	274-644 EB	Surface/base replacement	494
9/30/74	538-644 EB	Surface/base replacement	586
10/ 1/74	433-644 EB	Surface/base replacement	588
10/ 2/74	209-328 EB & WB	Surface/base replacement	230
10/ 4/74	209-692 EB & WB	Spot seal patching	849
10/28/74	274-538 EB & WB	Patch potholes	286
10/30/74	274-644 EB	Patch potholes	465
11/22/74	380-390 EB	Spot seal patching	595
2/ 7/75	221-274 EB & WB	Spot seal patching	418
2/24/75	327-354 EB	Spot seal patching	567
5/23/75	208-592 WB	Flush coat reclamite	8,041
5/30/75	500-692 WB	Flush coat reclamite	3,944
6/ 5/75	275-644 EB	Surface/base replacement	859
6/23/75	221-644 EB & WB	Surface/base replacement	823
6/24/75	433-644 EB	Surface/base replacement	1,036
6/25/75	433-644 EB	Surface/base replacement	1,196
6/26/75	539-644 EB	Surface/base replacement	1,286
6/27/75	486-644 EB	Surface/base replacement	2,146
6/28/75	208-644 EB	Surface/base replacement	838
6/28/75	221-505 EB	Rubberized seal coat	53,614
6/29/75	221-505 EB	Sand bleeding seal	1,307
6/30/75	538-644 EB	Surface/base replacement	1,304
Total Cost up to 6/30/75			$176,393

TABLE 22A
Historical Project Costs

Cost of 1 Inch AC (In-Place)
Based on New Construction

	Sq. Yards ( ) x 1000		Quantity ( ) Tons Unit Cost/Ton		Equivalent Thickness ( )		
Project	Year Built	Length Miles	Asphalt	AC	Cost/Yd^2	Cost/Lane* Mile	Total Cost of Project
		(294)	(8729)	(152,500)	(10")		
I17-2(46)	75	6.6	85.00	4.70	.496	3492	10,679,440
		(130)	(2850)	(45,275)	(6")		
RS274(2)	75	5.6	85.00	5.50	.629	4428	1,434,059
		(54)	(1004)	(18,200)	(6")		
U356(2)	75	1.4	85.00	9.00	.763	5372	1,011,466
		(40)	(941)	(16,500)	(7")		
RSG204(4)	75	1.4	87.74	10.28	.892	6282	1,181,541
		(343)	(14,360)	(260,130)	(10")		
I10-6(50)	75	23.4	89.00	5.65	.714	5027	8,463,060
		(492)	(14,855)	(265,300)	(10")		
I10-2(47)	75	22.8	83.50	4.90	.516	3632	3,992,961
		(268)	(4326)	(70,325)	(6")		
RF016-1(18)	75	4.0	93.00	8.00	.601	4230	2,459,867
		(58)	(1449)	(30,162)	(8")		
FF022-2(10)	UW	1.5	100.00	7.50	.803	5652	1,110,582
		(67)	(1530)	(24,000)	(6")		
RS274(5)	75	2.8	100.00	3.50	.592	4168	796,927
		(69)	(2208)	(45,620)	(9")		
F023-1-505	75	4.0	88.00	6.00	.751	5287	1,023,738
		(142)	(3959)	(75,100)	(7")		
I19-1(57)	UW	6.1	80.00	5.10	.706	4969	4,321,579
		(81)	(1803)	(32,800)	(6")		
RS370(3)	UW	4.1	85.00	8.00	.853	6005	2,908,479
		(83)	(1895)	(36,120)	(5")		
I-I68-1(62)	UW	1.5	80.00	5.00	.802	5647	2,441,947
		(67)	(1552)	(31,050)	(7")		
F002-2-503	UW	2.0	85.00	6.00	.678	4773	970,437
		(524)	(17,564)	(351,325)	(9")		
I40-2(76)	UW	23.6	90.00	7.00	.857	6034	8,150,276
		(235)	(7101)	(134,000)	(7")		
I19-1(41)	UW	10.7	90.00	4.50	.756	5321	6,227,312
		(273)	(6843)	(129,070)	(8")		
I17-2(63)	UW	20.1	90.00	6.00	.965	6795	5,315,311

*Lane Mile = 7040 yd^2

TABLE 22A (Continued)
Historical Project Costs

Cost of 1 Inch AC (In-Place)
Based on Overlay Construction

	Sq. Yards ( ) x 1000		Quantity ( ) Tons Unit Cost/Ton		Equivalent Thickness ( )		
Project	Year Built	Length Miles	Asphalt	AC	Cost/Yd^2	Cost/Lane Mile	Total Cost of Project
F033-1-501	75	(262) 13.1	(3146) 87.00	(46,600) 11.11	(3") 1.008	7099	988,023
S371-508	75	(57) 1.4	(185) 80.00	(3845) 12.50	(1.5") .416	2925	102,238
F037-1-503	75	(263) 16.0	(3400) 105.00	(46,500) 14.00	(3") 1.278	8999	1,223,670
RF029-1(2)	75	(365) 15.6	(6500) 90.00	(127,200) 5.00	(5") .636	4480	1,834,384
RS366(6)	75	(84) 2.3	(2127) 95.00	(40,500) 9.00	(8.5") .794	5590	1,357,520
S357-502	75	(119) 7.8	(840) 125.00	(16,000) 3.75	(2") .693	4875	212,525
S282-512	75	(230) 14.00	(2745) 87.00	(27,500) 11.00	(2") 1.177	8283	728,377
FOS1-2-504 FO44-1-505	75	(161) 4.7	(2357) 90.00	(33,670) 9.00	(4") .798	5616	689,465
S215-906	75	(186) 8.8	(1095) 92.00	(20,665) 5.00	(2") .548	3856	441,998
I10-5(46) I10-6(74)	75	(489) 26.0	(2808) 92.00	(52,845) 7.40	(1.75") .758	5338	1,821,597
I40-5(44)	75	(859) 23.6	(4236) 97.00	(97,600) 9.00	(1.25") 1.201	6900	3,797,031
I40-4(45)	75	(422) 11.6	(2284) 97.00	(45,800) 9.25	(1.25") 1.223	7037	1,992,703

TABLE 22A (Continued)
Historical Project Costs

Cost of 1/2 Inch ACFC
Based on New Construction

	Sq. Yards ( ) x 1000		Quantity ( ) Tons Unit Cost/Ton		Equivalent Thickness ( )		
Project	Year Built	Length Miles	Asphalt	ACFC	Cost/Yd^2	Cost/Lane Mile	Total Cost of Project
I17-2(46)	75	(224) 6.6	(486) 85.00	(7470) 14.00	.650	4577	10,679,440
U356(2)	75	(54) 1.4	(96) 85.00	(1740) 18.00	.725	5104	1,011,466
RS-RSG204(4)	75	(40) 1.4	(64) 87.74	(1155) 16.28	.605	4260	1,181,541
I10-6(50)	75	(343) 23.4	(835) 89.00	(12,820) 11.00	.540	3802	8,463,060
I10-2(47)	75	(492) 22.8	(595) 83.50	(10,810) 10.00	.389	2738	3,992,961
FF022-2(10)	75	(58) 1.5	(140) 100.00	(2332) 9.00	.605	4260	1,110,582
F023-1-505	75	(69) 4.0	(147) 88.00	(2450) 14.00	.682	4802	1,023,738
I19-1(57)	75	(142) 6.1	(263) 80.00	(4390) 8.00	.397	2793	4,321,579
I-I68-1(62)	75	(83) 1.5	(247) 80.00	(4122) 10.00	.737	5186	2,441,947
F002-2-503	75	(67) 2.0	(130) 85.00	(2160) 12.00	.551	3882	970,437
I40-2(76)	75	(524) 23.6	(948) 90.00	(15,800) 12.00	.525	3695	8,150,276
I19-1(41)	75	(235) 10.7	(439) 90.00	(7330) 11.00	.512	3604	6,227,312
I17-2(63)	75	(273) 20.1	(1047) 90.00	(16,109) 11.00	.995	7005	5,315,311
S371-50B	75	(57) 1.4	(71) 80.00	(1090) 18.00	.446	3140	102,238
RS366(6)	75	(84) 2.3	(153) 95.00	(2550) 11.00	.507	3570	1,357,520
I10-5(46) I10-6(74)	75	(489) 26.0	(885) 92.00	(13,625) 8.40	.400	2818	1,821,597
I40-5(44)	75	(859) 23.6	(1098) 97.00	(18,300) 14.00	.422	2426	3,787,031
I40-5(45)	75	(422) 11.6	(533) 97.00	(8220) 15.00	.414	2382	1,992,703

TABLE 22A (Continued)
Historical Project Costs

Cost of 1/2 Inch ACFC Based on Heater Scarification

	Sq. Yards ( ) x 1000		Quantity ( ) Tons Unit Cost/Ton		Equivalent Thickness ( )		
Project	Year Built	Length Miles	Asphalt	ACFC	Cost/Yd^2	Cost/Lane Mile	Total Cost of Project
F022-3-983	74	(341) 14.9	(563) 75.00	(10,235) 12.27	.492	3464	288,888
F022-3-974	74	(115) 2.7	(177) 80.00	(3225) 11.27	.439	3089	110,556
F012-1-915 F016-1-908	74	(86) 2.3	(143) 80.00	(2610) 12.35	.503	3541	98,916
F003-3-902	74	(42) 1.0	(96) 80.00	(1480) 20.00	.882	6213	66,574
I17-1-950	75	(98) 2.6	(210) 80.00	(3515) 20.00	.893	6287	164,013
F022-3-987	UW	(244) 5.0	(515) 100.00	(8530) 9.18	.533	3751	236,543

Cost of Asphalt Rubber Plus Chips

	Sq. Yards ( ) x 1000		Quantity ( ) Tons Unit Cost/Ton				
Project	Year Built	Length Miles	Chips	Asphalt Rubber	Cost/Yd^2	Cost/Lane Mile	Total Cost of Project
F011-1-906	72	(49) 2.3	(1700) 18.89	(246) 230.00	1.826	12,855	98,403
F022-1-508 S294-501	72	(222) 11.9	(1800) 48.00	(405) 230.00	.810	5,702	194,792
F026-2-504	74	(210) 10.5	(1550) 25.00	(343) 220.00	.545	3,837	145,800
F037-1-909	73	(171) 10.4	(1423) 25.00	(320) 220.00	.620	4365	140,185
F022-1-509	74	(287) 14.4	(3900) 13.35	(490) 200.00	.522	3675	171,850
I10-6-910	74	(193) 13.7	(3080) 14.00	(325) 250.00	.645	4541	139,296
I40-4-914 I40-4-915	74	(422) 29.8	(5205) 26.50	(669) 236.00	.701	4935	325,738
F022-4-923	74	(114) 5.4	(1830) 14.00	(187) 250.00	.681	4794	85,528
S440-918	UW	(531) 26.6	(7300) 22.63/C.Y.	(900) 266.13	.762	5364	449,040
I40-4-920	75	(76) 5.4	(1000) 17.87	(120) 247.00	.625	4400	55,009
S441-914	UW	(217) 15.4	(3120) 26.00	(374) 255.00	.810	5702	192,565
I40-5(44)	75	(859) 23.6	(8800) 16.50	(1475) 225.00	.556	2330	3,787,031
I40-5(45)	75	(422) 11.6	(2220) 31.50	(800) 255.00	.650	2664	1,992,703

DEPARTMENT OF TRANSPORTATION
STATE OF ARIZONA

TABLE 22A (Continued)
Historical Project Costs

Cost of Heater Scarification Plus Emulsified Petroleum Resin (EPR)

Heater Scarification with 1/2" ACFC

	Sq. Yards ( ) x 1000		Quantity ( ) Tons Square Yards (S.Y.) Unit Cost/Ton				
Project	Year Built	Length Miles	EPR	Heater Scarification	Cost/Yd^2	Cost/Lane Mile	Total Cost of Project
I17-1-937	72	3.0	(57) 100.00	(135,870) S.Y. .08/S.Y.	.227	1598	68,440
F022-2-925	71	8.2	(80) 140,00	(192,165) .08/S.Y.	.138	971	98,838
F022-2-924	72	3.6	(71) 160.00	(170,540) .11/S.Y.	.177	1246	126,262
I17-1-938	72	5.6	(31) 150.00	(71,930) .20/S.Y.	.265	1863	58,332
F022-3-965	72	5.4	(52) 130.00	(123,655) .13/S.Y.	.185	1300	82,466
F022-3-525	73	3.0	(110) 150.00	(132,540) .16/S.Y.	.284	2003	111,045
I17-1-943	74	6.0	(48) 128.70	(128,900) .52/S.Y.	.568	3998	139,689
S264-910	73	5.0	(38) 230.00	(100,135) .24/S.Y.	.327	2304	108,918
S261-906	73	7.7	(54) 230.00	(143,800) .36/S.Y.	.446	3142	145,963
F045-1-911	73	8.4	(50) 200.00	(134,110) .23/S.Y.	.305	2144	147,137
F022-5-906	74	8.1	(72) 175.00	(191,800) .26/S.Y.	.326	2293	196,140
F022-3-976	74	1.5	(31) 200.00	(53,000) .35/S.Y.	.467	3288	88,888
F022-1-907 F022-2-928	74	(261) 8.2	(105) 145.00	(261,200) .15/S.Y.	.208	1466	227,704
I10-5(47)	UW	(215) 15.4	(108) 200.00	(215,300) .20/S.Y.	.300	2114	1,012,432
F022-3-983	74	(341) 14.9	(171) 165.00	(341,165) .16/S.Y.	.243	1709	288,888
I10-2(63)	74	(33) 3.6	(16) 240.00	(32,940) .25/S.Y.	.367	2581	563,875
F022-3-974	74	(115) 2.7	(58) 178.00	(115,100) .20/S.Y.	.290	2039	110,556
F022-4-510 S207-503	75	(170) 5.6	(85) 190.00	(170,350) .21/S.Y.	.305	2146	698,131
F012-1-915 F016-1-908	74	(86) 2.3	(54) 200.00	(86,840) .18/S.Y.	.304	2143	98,916
F003-3-902	74	(42) 1.0	(32) 200.00	(42,245) .22/S.Y.	.371	2615	66,574
I17-1-950	75	(98) 2.6	(61) 210.00	(97,580) .30/S.Y.	.431	3036	164,013
F022-3-987	UW	(244) 5.0	(155) 195.00	(243,650) .15/S.Y.	.274	1929	236,543

TABLE 22A (Continued)
Historical Project Costs

Heater Scarification with AC Overlay

	Sq. Yards ( ) x 1000		Quantity ( ) Tons Square Yards (S.Y.) Unit Cost/Ton				
Project	Year Built	Length Miles	EPR	Heater Scarification	Cost/Yd^2	Cost/Lane Mile	Total Cost of Project
F053-2-501	74	(110) 6.9	(55) 210.00	(110,800) .21/S.Y.	.314	2212	195,674
F022-3-986	75	(123) 2.0	(62) 90.50	(123,000) .24/S.Y.	.286	2011	141,154
F022-3-530 S253-507	75	(107) 2.1	(67) 220.00	(106,700) .15/S.Y.	.288	2029	307,775
F053-2-502	75	(143) 9.4	(90) 180.00	(142,950) .20/S.Y.	.313	2206	331,350
F022-1-510	UW	(262) 12.6	(165) 200.00	(261,900) .25/S.Y.	.376	2647	580,835
F026-2-507	UW	(11) 3.7	(55) 150.00	(11,310) .40/S.Y.	1.129	7951	689,465
S215-906	UW	(153) 8.8	(118) 205.00	(152,580) .35/S.Y.	.509	3580	441,998

Appendix B

Material and Process Specifications

Asphalt Rubber – Test Sections 1 and 3

PAVING ASPHALT (Seal Coat With Ground Tire Rubber)
(Grade 120–150 Penetration, Los Angeles Basin)

Paving asphalt shall be Grade 120–150 penetration produced of crude oil from the Los Angeles Basin.

The ground tire rubber shall have a specific gravity of 1.13 to 1.17 and shall be free of fabric, wire, or other contaminating materials. To prevent particles of rubber from sticking together, up to four percent by weight of the rubber can consist of calcium carbonate.

The equipment used and the methods employed for combining the rubber and asphalt mixture shall employ means such that percentages of the two materials can be readily determined and controlled. The proportions of materials by weight shall be 73–77 percent asphalt and 27–23 percent reclaimed rubber.

The materials shall be thoroughly and rapidly combined for such a time and at such a temperature that the consistency of the mixture approaches that of a semi-fluid material.

At least 95 percent of the rubber compound shall pass a No. 16 sieve and not more than 15 percent of the rubber shall pass a No. 25 sieve when the mixing procedure involves intimate contact between the hot asphalt and rubber for a period of ten minutes or more. The sieves shall conform to the requirements of AASHO M-92. Temperature of the asphalt shall be approximately 375°F at the start of mixing.

After the mixture has cooled and reached application consistency, the mixture may be diluted by approximately five percent by weight of the mixture with kerosene or other approved petroleum solvent to facilitate application.

Tack Coat

LIQUID ASPHALT (Tack Coat, Graded MC–250 or RC–250)
Except as where otherwise specified, a bituminous tack coat of Grade MC–250 or RC–250 Liquid Asphalt shall be applied to the existing bituminous surface prior to the placing of asphaltic concrete, and to the asphaltic concrete prior to the placing of asphaltic concrete for finishing course. The amount applied shall be approximately 0.06 gallons per square yard.

Reclamite Test Sections 16, 17, and 18

EMULSIFIED PETROLEUM RESIN (Flush Coat)
Emulsified Petroleum Resin shall conform to the requirements of the Supplemental Specifications.

Measurement of this material will be by ton of undiluted Emulsified Petroleum Resin furnished, and applied in accordance with the requirements specified herein.

Petroset Test Sections 1 and 14

EMULSION (Petroset) (For Tack Coat)
This item consists of furnishing an emulsion and applying it as specified.

The emulsion shall be manufactured by the Phillips Petroleum Company and known as Petroset.

The following properties shall characterize the emulsion:

Physical State	Free flowing, oil in water emulsion
Color	Green
Sieve Test, No. 100 Sieve, percent retained	Maximum 0.1
Specific Gravity	1.00 ± 0.03
Brookfield Viscosity*	20–80
Solids Content, percent	62 ± 2
Particle Charge	Positive
pH	5.5 to 6.5
Storage Stability	Excellent at temperatures 50 – 100 degrees F
Heat Stability	Minimum 24 hours at 140 degrees F
Cold Stability	Minimum 24 hours at 40 degrees F
Miscibility with water	Unlimited

*2:1 dilution, LVT model, No. 1 spindle, 12 RPM, 75 degrees F

Emulsified Asphalt

EMULSIFIED ASPHALT (Seal Coat, With Rubber)
Emulsified Asphalt shall be formed using a base asphalt having an absolute viscosity of 1,300 to 1,800 poises, at 140°F and a cationic emulsifying agent.

Rubber shall be added to the emulsion in the form of Latex. The Latex shall be a butadiene-styrene, low-temperature polymer with a monomer ratio of 70 (butadiene) to 30 (styrene).

The Latex shall be added to the emulsifying agent and water prior to emulsification. Latex shall be added in sufficient amount to provide a minimum rubber solids content of five percent by weight of the residual emulsion asphalt.

The Saybolt Furol Viscosity, at 122°F, of the formed emulsion system shall be between 75 and 400 seconds and the particle charge test shall have a positive indication.

The contractor shall furnish the engineer with a certificate which will certify:

(1) The test results of the Latex used.
(2) The amount of Latex incorporated into the emulsion.
(3) The stability of the emulsion and Latex.

The contractor shall furnish the Materials Division with a sample of the base asphalt and the Latex furnished for incorporation into the emulsion prior to emulsification.

Asphaltic Concrete – All Test Sections Except 5

ASPHALTIC CONCRETE
Except as otherwise specified, the asphaltic concrete to be used on this project shall conform to the following:

Asphaltic concrete shall be produced by the use of a job-mix formula.

The bituminous material to be used shall be either 60–70 or 85–100 penetration paving asphalt, the amount being 10% by weight.

Mineral aggregate shall generally conform to the requirements of the Specifications for Type MA-2, except that it shall meet the following grading requirements within the range of the specified tolerances:

Passing Sieve	Percent	Tolerance, Percent
3/4 inch	100	±7
1/2 inch	96	±7
3/8 inch	92	±7
No. 4	74	±5
No. 8	46	±4
No. 40	16	±4
No. 200	4	±0.3

The asphaltic concrete to be placed on Test Section 5 shall comply with the above requirements, except as modified per the following:

The amount of paving asphalt to be used shall be approximately 14 percent by weight of total materials, and an anti-stripping agent shall not be added to the asphalt.

Asbestos, conforming to the requirements specified under Item 4060551 – Asbestos, shall be added to the mineral aggregate as a mineral filler.

The amount to be used shall be approximately 3.2 percent by weight of the Asphaltic Concrete. The method of adding the asbestos shall be approved by the engineer.

In order to distribute the asbestos properly, it will be necessary to mix the aggregate and the asbestos for approximately 15 seconds prior to the application of the bituminous material.

The temperature of the aggregate shall be between 300 and 330°F at time of mixing.

The use of pneumatic tired rollers in the initial and final breakdown shall be limited to an extent permitted by the engineer.

Asphaltic Concrete – Test Section 11

ASPHALTIC CONCRETE (Open Graded)
Mineral aggregate shall generally conform to the requirements of Specifications for Type MA–2, except that grading shall be as follows:

Sieve Size	Percent Passing
1 inch	100
3/4 inch	90 – 100
1/2 inch	70 – 85
3/8 inch	55 – 70
No. 4	30 – 50
No. 40	10 – 20
No. 200	3 – 6

Drying of the mineral aggregate and bin separation of the material will not be required. Temperature requirements of the aggregate for plant mixing and the moisture content requirements for the mineral aggregate are deleted.

It will be determined if mineral aggregate meets the grading requirements and is acceptable just prior to adding the bituminous material for mixing.

The bituminous material used shall be CSS–1h emulsified asphalt, and approximate amount used shall be 10 percent by weight of the total mixed material. An anti-stripping agent shall not be added to the asphalt.

All Sections Except No. 1 and No. 6

ASPHALTIC CONCRETE FOR FINISHING COURSE
Mineral aggregate shall conform to the requirements of the Specifications for Type MA–6, except that grading shall be as follows:

Sieve Size	Percent Passing
3/8 inch	100
No. 4	25 – 55
No. 8	0 – 12
No. 200	0 – 4

There is no requirement for crushed faces of aggregate produced from the designated source.

The bituminous material used shall be either 60–70 or 85–100 penetration paving asphalt, and the approximate amount used shall be 11 percent by weight of the total mixed materials.

Mineral Filler – Test Section No. 5

MINERAL FILLER (Asbestos)
This item consists of furnishing asbestos to be added as a filler to the asphaltic concrete placed on Test Section No. 5.

Asbestos fiber shall be chrysotile asbestos, coalinga type, or an approved equal, conforming to the following requirement:

Ro-tap Test (100 grams for 3 minutes)
+65 mesh, 40 percent minimum
Procedure B2, modified, of the QAMA*

Wet Wash:
+200 mesh, 20 percent minimum
Procedure C4, of the QAMA*

Penetration Efficiency:
70–95 percent
Johns-Manville Procedure
*Quebec Asbestos Mining Association

The asbestos shall be stored in such a manner as to be protected from water and moisture. Asbestos which is either wet or damp shall not be used.

Heater Scarification – Test Section 1 and 18

REJUVENATION OF EXISTING BITUMINOUS SURFACE
This item shall consist of the rejuvenation of the existing bituminous surface at locations specified under Test Section 18, and at the location specified under Test Section 2.

Prior to beginning heater-scarifier operations, the existing surface shall be cleaned of any loose material, soils, or aggregates that might interfere with subsequent operations. The use of power booms supplemented, if necessary, by the use of hand brooms will be required in order that the surface is free from any deleterious material. Holes in the existing surface, as specified by the engineer, shall be cleaned out and filled with mixed bituminous surfacing and this material shall be compacted. This material shall be acceptable to the engineer.

The equipment required for the rejuvenation work shall be a self-propelled, self-contained unit or a combination of self-contained units specifically designed to evenly heat the existing surface such that the surfacing materials can be scarified to a depth of at least 3/4 inch. The machine or machines shall be capable of operating at speeds of from 5 to 70 feet-per-minute, and of covering a minimum of 2,000 square yards per hour.

The heating unit shall be adjustable in width from 8 to 14 feet and shall have ports which will permit fuel and forced air injection for proper combustion without producing excessive smoke.

The scarifier shall be adjustable in width from 2 to 13 feet and shall be capable of scarifying depressions in the surface of up to 2 inches.

The width of the pass made by the scarifier shall be six inches greater than the width of the asphaltic concrete being laid by the laydown machine. The scarified material shall be left on the surface in an evenly spread condition without having been pulverized, thrown or broken. At least 80 percent of the material shall be spun or tumbled and the temperature of the scarified material, measured within three minutes after treatment, shall be at least 225°F.

Operations shall be scheduled such that there is a minimum distance between the heater-scarifier and the laydown machine; however, at no time on Test Section 18 shall this distance exceed 1,000 feet.

Petromat – Test Section No. 12

PETROMAT
This item shall consist of furnishing and applying a product manufactured by the Phillips Petroleum Company known as Petromat.

Petromat shall be a non woven polypropylene fabric, black in color, with a minimum tensile strength, in either direction, of 50 pounds-per-inch of width. The material, wet or dry, shall have an elastic recovery at 15 pounds, of 100 percent.

The approximate rate of application shall be 4 ounces per square yard.

Matting – Test Section No. 13

MATTING (Fiberglass)
This item shall consist of furnishing and applying a product manufactured from multiple length, chopped glass strands bonded with water-soluble polyester resin. The matting shall weigh approximately 1.5 ounces per square foot.

The matting to be used shall conform to Pittsburgh Plate Glass Company ACM 1 or shall be an equal and acceptable alternate.

The approximate rate of application shall be 1.5 ounces per square Foot.

Pre-Coated Chips – Test Section No. 2

COVER MATERIAL (Seal Coat, Special)
Cover material shall conform to the requirements of Standard Specifications for Section 704.

Grading shall be as follows:

Sieve Size	Percent Passing
1/2 inch	100
3/8 inch	85 – 100
1/4 inch	0 – 10
No. 8	0 – 5
No. 200	0 – 2

Abrasion shall not exceed 40 percent and there is no requirement for crushed faces.

Cover material may be obtained from any source provided the material conforms to the requirements specified herein. The contractor shall submit at least 75 pounds of the proposed material at least two weeks prior to application of the cover material.

Cover material shall be precoated. The material shall not contain more than one percent moisture at time of precoating. The bituminous material used to precoat the cover material shall be Grade 85–100 penetration paving asphalt. Approximately one percent, by weight of the cover material, paving asphalt shall be used.

The cover material and paving asphalt shall be mixed in accordance with requirements of subsection 406-3.04 of the Standard Specifications. Bin separation will not be required.

DEPARTMENT OF TRANSPORTATION STATE OF ARIZONA

ARIZONA HIGHWAY DEPARTMENT
MATERIALS DIVISION

LABORATORY BITUMINOUS MIXTURE DESIGN
Pit No. 1245

AC Mix Design for Minnetonka – East

MATERIALS SURVEY(PE) PRELIMINARY DESIGN GRADING							AS PRODUCED (CONSTRUCTION) FINAL ADJUSTED DESIGN GRADING				
					ADJ. CRUSH GRADATION		AS CRUSHED ON PROJECT		AS ADJ. IN LABORATORY		SPEC. LIMITS SOUGHT
Sieve	% Ret	% Pass	% Ret	% Pass	% Ret	% Pass	Composite		Composite		
3'' Slot	FINE		COARSE						FINE 80 %		
3''	STOCKPILE		STOCKPILE						COARSE 20 %		
2½''							%		%		
2''							%		%		
1½''							% Ret	% Pass	% Ret	% Pass	
1''											
¾''	0	100	0	100					0	100	
½''	1	99	16	84					4	96	
⅜''	0	99	22	62					4	92	
¼''	1	98	37	25					8	84	
No. 4	10	88	11	14					10	74	
8	34	54	3	11					28	46	
10	6	48	1	10					5	41	
16	13	35	1	9					11	30	
30	11	24	1	8					10	20	
40	5	19	1	7					4	16	
50	4	15	1	6					3	13	
100	6	9	1	5					5	8	
200	3	6	2	3					3	5	

SP. GR. Coarse Aggr. 2.182 SP. GR. Fine Aggr. 2.604 SP. GR. Comb. 2.494

Absorp. Coarse Aggr. 6.53 % Absorp. Fine Aggr. 1.83 % Absorp. Comb. 3.05

O.D. SP. GR. O.D. SP. GR. O.D. SP. GR.

	LL	PL	PI	Swell 24 hr.	Swell 48 hr.	S.E.
CRUSHED ROCK	%	%	NP	0.11 in.	0.19 in.	71
Crushed Fines	%	%	NP	0.07 in.	0.08 in.	81

ABRAISION% Loss B 100 Rev. 5 500 Rev. 23

REMARKS PLUS 3500 FT. — PLUS 8" RAINFALL

HIGH SWELL

THIS IS A VOLCANIC CINDER AGGREGATE

IT IS NOT FELT THAT THE ORDINARY VOIDAGE DESIGN
CRITERIA ARE APPLICABLE IN THEIR USUAL RANGES

AHD 44-9117 R4-71

DESIGN DATA

Specimen	A	B	C	D	E	F	Design Spec.
Temperature							
Bulk Density Lbs. Per Cu. Ft.		119.1	125.2	121.1	124.7		
Bit. Grade 85 - 100							
% of Bit.	9.0	9.5	10.0	10.5	11.0		
Density Lbs. Per Cu. Ft.	129	126	124	116	121		
Stabilometer	42	41	47	40	47		
Cohesiometer	43	36	65	41	77		
Voids		12.7	7.7	10.1	6.9		
V.M.A.		28.8	25.6	28.4	26.7		
% Voids Filled		55.9	69.9	68.8	74.2		
Effective Asphalt Total Mix		8.52	9.02	9.53	10.03		

Sample	Air PSI	H_2O PSI	Retention	
No. 1	334	223	67 %	10.0 % 85-100 Asphalt
No. 2	334	359	107 %	1.5 % Anti-Strip Agent
No. 3	334	486	146 %	2.0 % Dry Lime
No. 4	334	504	151 %	2.0 % Dry Cement

Max. Density 135.6 Lbs. Per Cu. Ft. (Rice Method) 10.0%

Asphalt 1.09 % Absorp. on dry aggregate

Film Strip. (Course Aggr.) =

C.K.E. Values F= 3.78 C= 8.09

Theoretical Bit. Ratio for Grade 85-100 Bitumen 6.4 %

Kc= 3.2 Kf= 1.4 Km= 1.7

Static Density @ 3000 psi& 10.0 % Bit=129.2 Lbs. Per Cu. Ft.

Recommended Bitumen Content Considering All Test Data 10.0 %±0.5%

Sieve	% Pass	Tol. % Total Wt. Pass
1''	100	
¾''	100	
½''	96	+4 TO -7 %
⅜''	92	± 7
No. 4	74	± 5
8	46	± 4
40	16	± 4
200	8	± 2

BLOTTER MATERIAL

Blotter material shall conform to the requirements of the first paragraph of subsection 706 (C) (2).

Grading shall be as follows:

Sieve Size	Percent Passing
3/8 inch	100
No. 4	80 – 100
No. 16	45 – 80
No. 200	0 – 15

Measurement will be made by the ton of blotter material furnished and applied.

SEAL COAT FOR SHOULDER DEMARCATION

Cover material to be used shall be Type CM-7 and shall be applied at the approximate rate of 38 pounds to the square yard.

Bituminous material to be used shall be Type CRS-2h (Special) emulsified asphalt, and shall be applied at an approximate rate of 0.50 gallons to the square yard.

Appendix C
Chronological Construction Summary

Date	Event
8–19–71	● Work begins – eastbound highway closed to traffic.
8–30–71	● Hot plant calibrated and AC adjusted to specifications. ● Heater scarification and overlaying (T.S. 18) begins at Station 495, traveling east to Station 692.
8–31–71	● Experienced AC compaction problems from Station 495 to 692. ● Contractor unable to provide 95% compaction.
9–3–71	● Petroset applied to cracks (T.S. 15). ● Reclamite applied to cracks (T.S. 16).
9–7–71	● Completed reclamite application (T.S. 16). ● Petroset applied to cracks (T.S. 15). Rained before emulsion broke, washing Petroset off roadway.
9–9–71	● Re-applied Petroset to cracks (T.S. 15). ● Applied reclamite flush coat and sand blotter (T.S. 17).
9–14–71	● Completed paving from Station 495 to 692 (T.S. 18). ● Paving operation moved to Station 208.
9–16–71	● Heater scarification, followed by Petroset application and overlay (T.S. 2).
9–21–71	● Completed heater scarification on eastbound roadway. ● Contractor moved operation to westbound roadway. ● Eastbound highway opened to two-way traffic, with no overlay from Stations 300 to 495.
9–24–71	● Heater scarification, reclamite flush and overlay started on westbound roadway. ● Modified AC mix composition, adding blend sand (blow sand) to mix.
10–4–71	● Vibratory roller used for compaction of AC on westbound highway.
11–10–71	● Completed AC placement on westbound roadway.

By this time weather conditions became too cold for AC placement. Overlay work was halted for the period 11–10–71 through 4–3–72, with numerous snow storms occurring during this period. These storms generally deposited only a few inches which quickly melted.

Date	Event
4–3–72	● Westbound highway carrying two-way traffic, with the eastbound highway closed to traffic.
4–4–72	● Considerable spalling of old pavement was found to have occurred on the eastbound highway during the winter. ● Contractor was paid force account money to fill these spalls (Stations 300 – 495).
4–17–72	● AC overlay placement began from Stations 445 to 473 (T.S.'s 14 and 15).
4–18–72	● AC overlay applied to Stations 473 to 483 (T.S. 16).
4–20–72	● Placed Petromat and fiberglass mats (T.S.'s 12 and 13).
4–27–72	● Completed AC section from Stations 483 to 495 (T.S.'s 16 and 17).
4–28–72	● Overlayed Petromat and fiberglass (T.S.'s 12 and 13). ● Fiberglass balling occurred in laydown machine. ● Petromat overlaying – no problem.
5–1–72	● Moved laydown machine to Station 300.

Date	Event
5–2–72	● Completed laydown from Stations 300 to 335. (T.S.'s 1, 3, and 4). ● Began and completed applying asbestos (T.S. 5) using 60/70 penetration oil.
5–3–72	● Overlayed 2-inch AC (T.S. 6).
5–4–72	● Removed 37 fiberglass balls from Test Section 13. Force account work.
5–8–72	● Paved 120/150 penetration AC from Stations 370 to 380 (T.S. 7). ● Hot plant temperature reduced – AC placed at 200°F instead of 240°F. ● Flushed old pavement from Stations 420 to 430 (T.S. 11) and blotted with blow sand.
5–9–72	● AC placed from Stations 385 to 395 with 40/50 penetration asphalt (T.S.8). ● Overlayed Test Section 9 using Four-Corners 120/150 penetration asphalt.
5–10–72	● Placed AC using 200/300 penetration asphalt (T.S. 10).
5–11–72	● Placed cold mix AC using emulsion (T.S. 11). This mixture very hard to place with laydown machine – considerable tearing. Finally placed with a blade.
5–12–72	● Flushed emulsion mixed AC (T.S. 11).
5–15–72	● Began ACFC placement on eastbound roadway.
5–17–72	● Latex emulsion (T.S. 4) deleted from project due to contractors inability to make and deliver on time.
5–18–72	● Asphalt rubber mix placed (T.S.'s 1 and 3). ● Rubberized sections could only be shot in 10 foot widths. This slowed the operation, allowing the mix to gel. This delay led to an application rate of 1.00 gallon/yd^2 on Test Section 1. ● Rubberized seal coat on Test Section 1 required sanding before opening to traffic. ● Excess rubberized mix was shot on Test Section 4 with cinder chips.
5–22–72	● Completed ACFC placement on eastbound roadway.
5–24–72	● Eastbound highway opened to traffic. ● Westbound highway remained open while ACFC was placed under traffic conditions. ● Necessary to water ACFC each day to prevent ACFC from being raveled off by traffic.
5–31–72	● Completed ACFC placement on westbound highway.
6–26–72 thru 6–29–72	● Placed rumble rock chip seal on distress lane.