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PREVENTION OF REFLECTIVE CRACKING MINNETONKA-EAST (1979 ADDENDUM REPORT)

Prepared by:
George B. Way
Senior Research Engineer
Research Section
206 S. 17th Ave.
Phoenix, Arizona 85007

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HIGHWAYS DIVISION · RESEARCH 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 sub surface 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 and Apprendix B of the previous report (1).

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	Fiberglas 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
18A	1-1/4" AC Overlay
18B	3" AC Overlay
18C	1-1/2" AC Overlay
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 1978 (approximately 6-1/2 years), the highway has been subjected to loads equivalent to over 1,000,000 18 kip cumulative

Climatic variations were rather severe during the test period with above average rainfall in 1972. Also, the test region had a Freezing index of 260 in the 1974-75 winter.

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 1978.

Interesting results are provided in Table 2 - 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 for those sections with no patching.* 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.

Also, it was found that basic asphalt properties influenced the reduction of reflective cracking. It was found that the 4.0 mega poise at 77 degrees F. viscosity (equivalent penetration about 45, absolute unaged viscosity of 3000 poises at 140 degrees 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 stability 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 pavement.

This report represents the culmination of over seven years of careful planning, construction, and objective data analysis. The results were a myriad of meaningful information which should be of value to

* Some types of treatments had extensive patched sections and this should be considered.

TABLE 2
EAST BOUND
1-1/4"AC 1/2"ACFC ASPHALT RUBBER SEAL COAT 1975

Test Section Number		% Reflected 1975	Cracking 1978
3 & 4	Asphalt Rubber Under ACFC	4.0	2.1
5	Asbestos Plus 3% Asphalt	13.0	5.9
18A	Heater Scarification Plus Reclamite	6.0	7.4
1	Asphalt Rubber Seal Coat Flushed Into AC Overlay	19.0	12.8
10	200/300 Penetration Asphalt	8.0	16.1
	Control Sections Without Patching	17.0	27.0

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:

- Asphalt rubber membrane seal coat under ACFC
- Asbestos plus 3 percent asphalt
- Heater scarification with reclamite (surface recycling)
- Asphalt rubber membrane flushed into asphaltic concrete overlay
- 200/300 penetration asphalt

Application considerations are as follows:

- One of the above treatments should be used in conjunction with a thin overlay (less than 4 inches of AC).
- Application using an asphalt rubber membrane seal coat under the AC or ACFC should be used with chips to provide direct transfer of vertical loads.
- Heater scarification should be to a depth of 3/4 inches or greater.
- The lowest possible viscosity AC asphalt with the slowest aging characteristics should be used.
- 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 less 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.

MINNETONKA REPORT
INTRODUCTION

The purpose of this addendum report is to bring the readers of the first report (1)(2) up to date with observed performance through April 1978. The preceding summary will help familiarize the reader with the previous report. For detailed historical background information the reader should consult the first report (1)(2).

Since publication of the first report considerable changes in the pavement rehabilitation program in the United States and Arizona have taken place. The three R (rehabilitation, restoration, resurfacing) program sponsored by the FHWA has focused the attention of all states on the importance of a total pavement management program incorporating not only overlays and special treatments but also such items as recycling and grinding or planning methods of restoration. This project deals with the feasibility of employing thin overlays (4 inches or less) to control reflective cracking. Since many of the test sections have now reached a terminal condition it is possible to examine overlay design methods and test how well they would have predicted overlay performance. From these results recommendations are made to improve the various overlay design methods.

Results of the first report have been incorporated into Arizona's Pavement Management System (3). In particular the photo interpretation of cracking has become a technique for inventoring the percent cracking of Arizona's state highway system, Appendix B details this procedure. Likewise the 10 percent cracking level has been selected as the threshold value which triggers the use of a special treatment in conjunction with a thin overlay. Results from this study continue to indicate that a thin overlay used in conjunction with a special treatment such as asphalt rubber or heater scarification can reduce reflective cracking as well as provide a safe smooth riding surface.

1. Way, G.B., "Prevention of Reflective Cracking in Arizona Minnetonka-East (A Case Study)," May 1976, Arizona Dept. of Transportation.

2. Way, George, "Tests on Treatments for Reflective Cracking," Transportation Research Record 647.

3. Finn, F., "Development of Framework For Pavement Management System," Dec. 1976, Report For Arizona Dept. of Transportation.

PERFORMANCE TEST RESULTS

To aid in interpretation of test results Table 1 gives traffic distribution since overlay construction.

Since 1973 and the oil embargo, the number of vehicles and loads has steadily increased, as such the overlay project has experienced well over 1,000,000 18kip load repetitions since construction.

Figures 1 and 2 show the average monthly temperature and rainfall since-construction. Winters have been mild in 1976-77 and 1977-78 with low freezing indexes.

TABLE 1

Year	ADT	Trucks	18kip Loads	Cumulative 18kip Loads
1971	9,237	2,780	161,372	161,372
1972	9,701	3,007	164,201	325,573
1973	10,000	3,200	158,123	483,696
1974	10,300	3,399	160,012	643,708
1975	10,600	3,604	159,213	802,921
1976	11,290	3,985	240,020	1,042,941
1977	11,635	4,107	260,172	1,303,113
1978	12,111	4,565	263,293	1,566,406

TABLE 2
EAST BOUND
1-1/4"AC 1/2"ACFC ASPHALT RUBBER SEAL COAT 1975

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10	200/300 Penetration Asphalt	8.0	16.1
	Control Sections Without Patching	17.0	27.0

Reflective Cracking Analysis

The heart of this study is in the relfective cracking analysis. The method of anlaysis is completely described in the previous report(1)(2) and this method has continued to be used each year. Table 1A in Appendix A gives the percent cracking before and after overlay for each year of the study. Table 2A shows considerable patching of the test sections has occurred. Table 2 shows the percent reflective cracking for those test sections that have not needed any maintenance patching.*

The above table shows that several treatments are still significantly controlling reflective cracking. By examining before and after crack information, Table 1A, it was possible to determine that the asphalt rubber seal coat placed in the summer of 1975 reduced cracking by 27 percent in 1976; however, by 1977 cracking had increased by 31 percent over the 1975 values. Evidently the asphalt rubber seal coat was able to reduce cracking for about one year. In many ways the performance of this seal coat was akin to the asphalt rubber seal coat over the original overlay. That is shrinkage cracks, in this case the reflective cracks, could not be controlled

* Some types of treatments had extensive patched sections and this should be considered.

FIGURES 1

AVERAGE MONTHLY TEMPERATURE

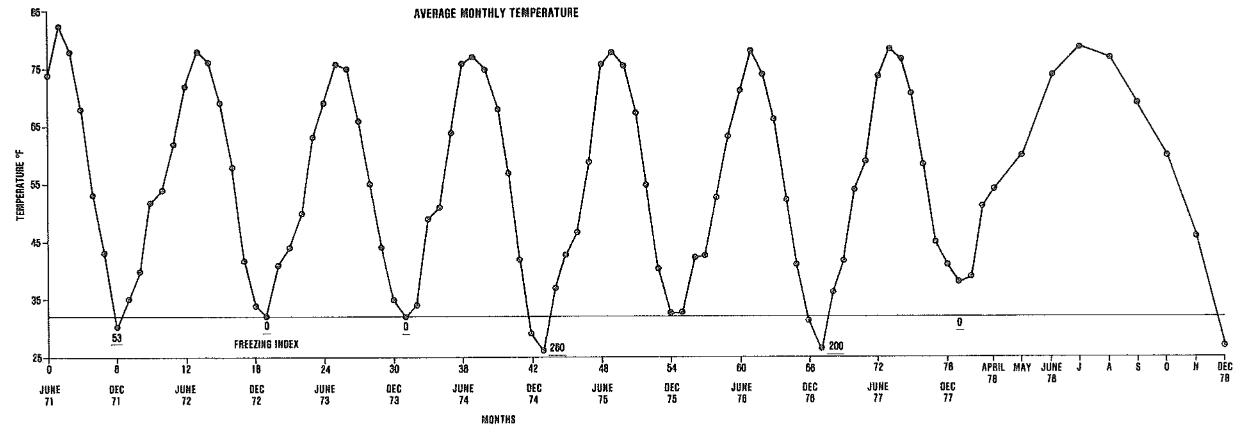
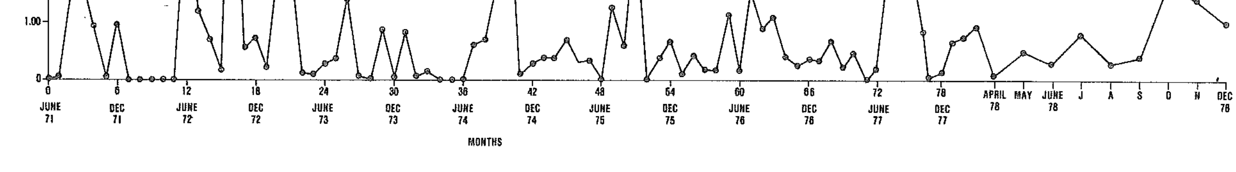


FIGURE 2

AVERAGE MONTHLY RAINFALL



beyond one year. This means the 1978 values in Table 2 are a good indicator of the capacity of the various original treatments to prevent reflective cracking. Interestingly enough the asbestos (TS 5) and asphalt rubber flush-in seal coat (TS 1) section have moved up substantially in the rankings. Evidently other than initial shrinkage cracks, which gave each section fair or poor rankings, no long-term fatigue type, pattern cracking has managed to show through. The 200/300 penetration section has continued to show more reflective cracking as the asphalt has continued to age; this was predicted in the first report. A similar crack ranking was done by comparing a test section to its adjacent control section by dividing the sum of the test section cracking Table 1A and patching Table 2A by the control section cracking and patching for 1978 data. Table 3A shows this ranking which is similar to Table 2.

As can be seen on Table 2A, considerable patching has been done throughout the project. To properly account for this, an AASHTO road test (4) approach was taken. Percent cracking was related to AASHTO cracking by examining all photos and developing the relationships shown on Figure 3.

Through regression analysis, percent cracking multiplied by 13.8 equals AASHTO lineal feet plus class 2 and 3 area of cracking in 1000 square feet of pavement. From this it was possible to plot AASHTO cracking plus patching versus cumulative 18kip traffic loads. Figure 4 shows this relationship and lists the order of ranking from poor to good. Test section 9, 11, 14 which are Four Corners 120/150 asphalt, emulsion treated base and petroset flush-in have all had their entire travel lane removed and replaced with patching material as of March 1978. Whereas those test sections shown on Table 2 have had virtually no patching. Interestingly the trend line curves tend to be concave upward.

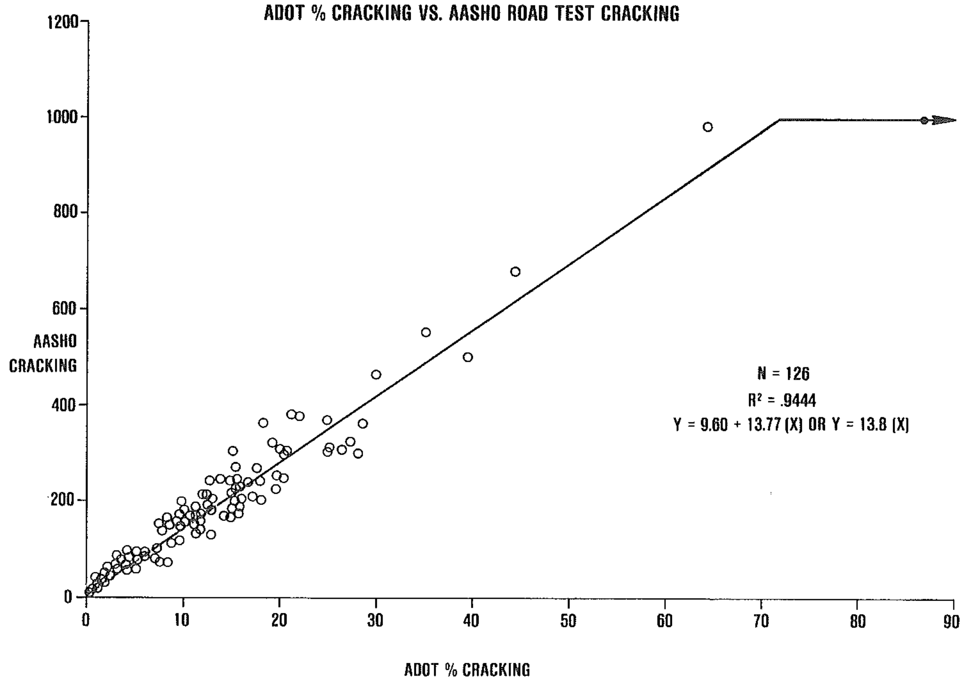
Other measures of performance besides cracking are also important.

Rideability

As in the previous report, each test section and control sections ride roughness was computed in inches per mile. To do this a set of multipliers were used to adjust for the mechanics of the Mays recording system (6.4 value). In addition, multipliers for different section lengths (500,1000, and 2000 feet) were determined. These multipliers were reported in the previous report; however, since 1976 all inventory Mays Ride Meter data has been reviewed by project, and it was found that a systematic change in vehicle response had taken place annually. To account for the change, annual correction factors have been determined by year in order to equate each year's data set with the previous year's information. If this were not done, an incorrect trend in roughness would be reported. That is, highways would appear to be becoming smoother with time. By applying these correction factors, the equivalent inches per mile for each section was computed and is shown on Table 4A. Figure 5 is a graphical representation of the change in roughness versus 18kip cumulative loads. All tests are ranked in order of increasing roughness as of August 1977. Amazingly the trend lines appear to be quite linear versus traffic. The test sections are ranked

FIGURE 3

ADOT % CRACKING VS. AASHO ROAD TEST CRACKING



4. "The AASHTO Road Test, Report 5, Pavement Research," 1962, Highway Research Board.

FIGURE 4

AASHO CRACKING PLUS PATCHING
VS. 18 KIP LOADS

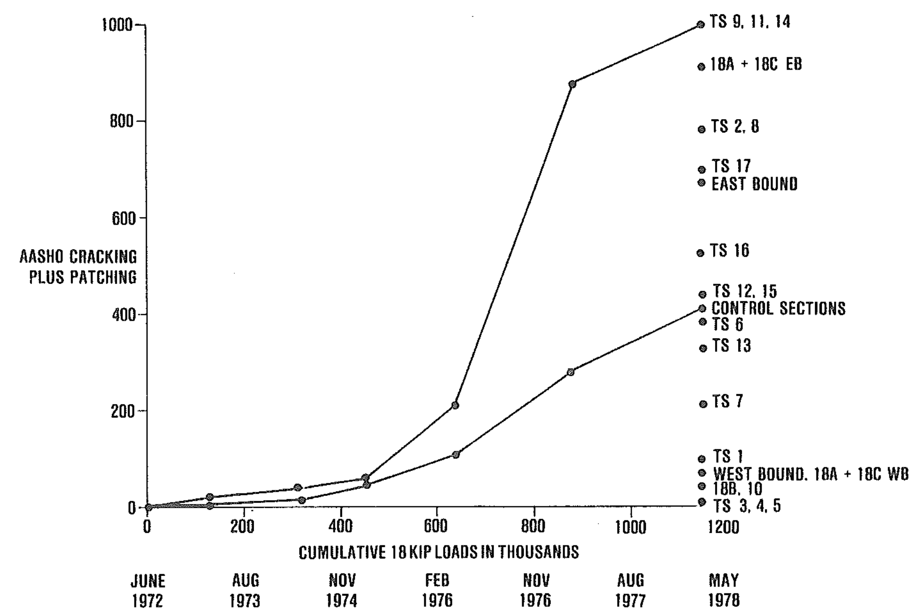
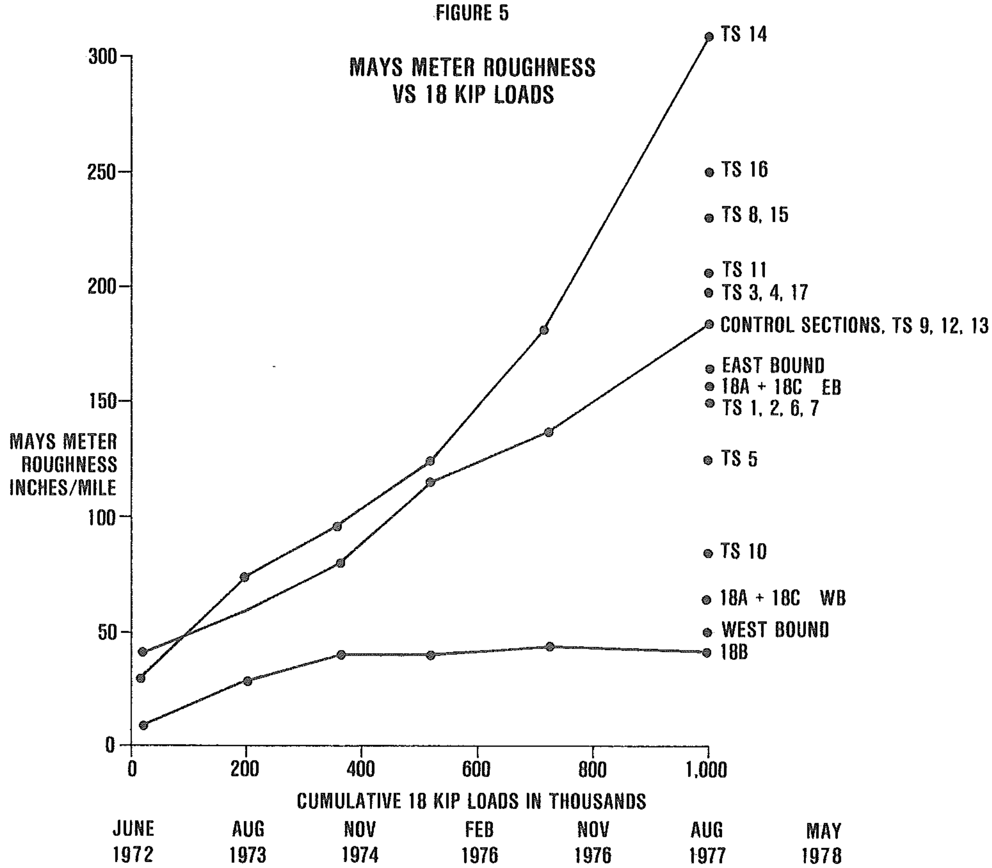


FIGURE 5

MAYS METER ROUGHNESS
VS 18 KIP LOADS



in order of increasing roughness. As such test section 14, petroset flush in (which was extensively patched), has the roughest ride. Test section 18B, the 3-inch AC plus 1/2" ACFC westbound section, has the smoothest ride. interestingly, test sections 1, 3 and 4 (all asphalt rubber) are somewhat rough. Evidently the application of a combined total of over one gallon per square yard of asphalt rubber on or near the surface of the pavement has lead to considerable shoving, creating a rather rough ride.

Rut Depth

Rut depths were measured with a four-foot-straight edge in the travel lane right wheelpath and are shown on Table 5A. The rate of rutting for all sections is plotted on Figure 6. All test sections are ranked in order of increasing rut depth. Test section 1 and 15 (asphalt rubber and petroset in cracks) have the deepest rut depth. Test section 5 (asbestos) has the shallowest rut depth. Again, those test sections (1, 3, 4) with considerable asphalt rubber at or near the surface have shown substantial rutting.

Deflection

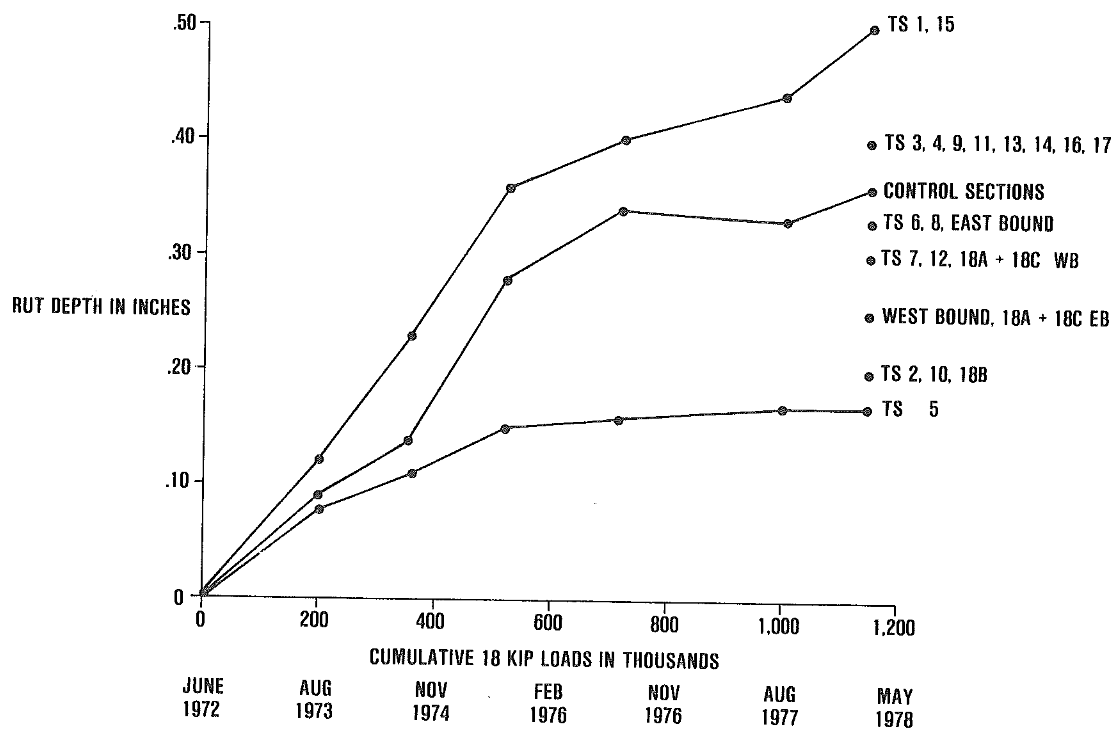
Dynaflect deflections, Table 6A and 7A, were taken through January 1977. In keeping with the first report(1) Figure 7 describes dynaflect deflection values by different sections. As can be seen trends established previously seem to be continuing. Test section 3 (asphalt rubber under the ACFC) continues to give lower deflection values.

Asphalt Properties

Asphalt properties of absolute viscosity at 140 deg. F., penetration at 77 deg. F. and micro-viscosity at 77 deg. F. are shown on Table 8A. Aging of all the asphalt began to slow down considerably with time. In a recent report (5) to the Association of Asphalt Paving Technologists the author describes the aging rate curve of Arizona. Asphalts at Minnetonka are following this behavior, in that considerable aging takes place in the first two to three years and then markedly slows down.

FIGURE 6

RUT DEPTH VS 18 KIP LOADS



5. Way, G.B., "Asphalt Properties and Their Relationship to Pavement Performance in Arizona," Feb. 1978, Association of Asphalt Paving Technologists.

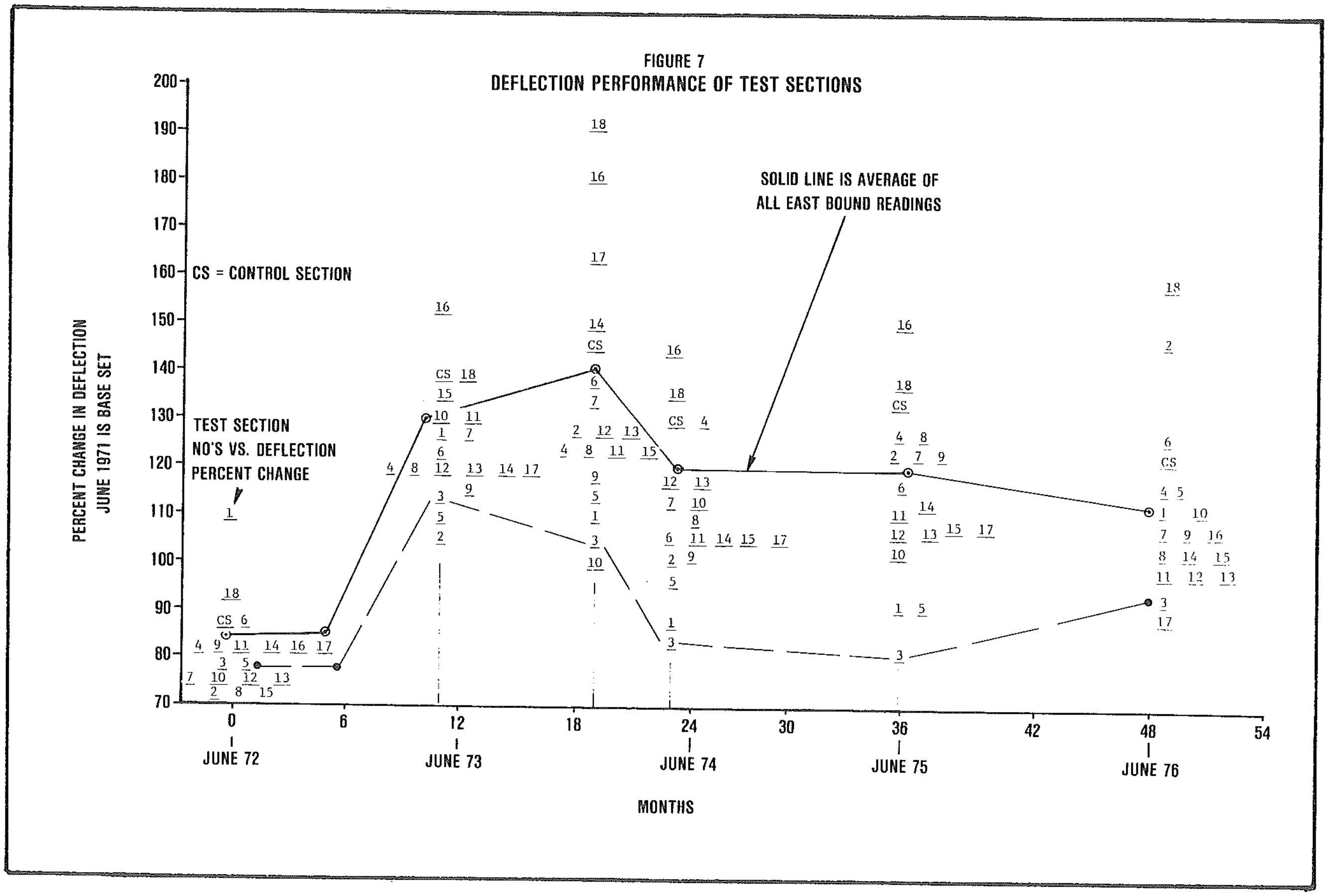


FIGURE 7
DEFLECTION PERFORMANCE OF TEST SECTIONS

ANALYSIS OF PERFORMANCE TEST RESULTS

By examining the previous information on cracking, rideability rut depth, deflection and asphalt properties it can be seen that a need exists to combine performance test results. For this case Present Serviceability Index (PSI) values were calculated for each test section. To do this cracking and patching were determined from photos and travel logs and rut depth by measurement with a four-foot-straight edge. To use Mays Ride Meter data, a relationship between roughness in inches/mile and slope variance was developed by equating Arizona's panel rating ride index Figure 1C to PSI. Since the Arizona Ride index was related to inches/mile of Mays Meter it was set equal to psi with the rut depth and cracking and patching term set to zero. Thus a slope variance for an equivalent ride index or inches/mile could be calculated. Figure 8 shows this relationship.

With this relationship plus the cracking, patching and rut depth information it was possible to calculate the PSI using the AASHTO road test equation (4). After performing the calculations Figure 9 was constructed to show the change in PSI verses 18kip cumulative loads. Test sections are ranked in order of decreasing performance. Test section 18B (3" AC plus 1/2" ACFC, heater scarification, west bound) at present has the highest PSI value. Likewise test section 14 has the poorest value, being substantially below the terminal 2.5 PSI value set for interstate highways. In addition Table 9A gives the correlation between AASHTO PSI and cumulative 18 kip traffic, in general correlation coefficients were above .9000.

FIGURE 8

MAYS RIDE METER ROUGHNESS VS. SLOPE VARIANCE

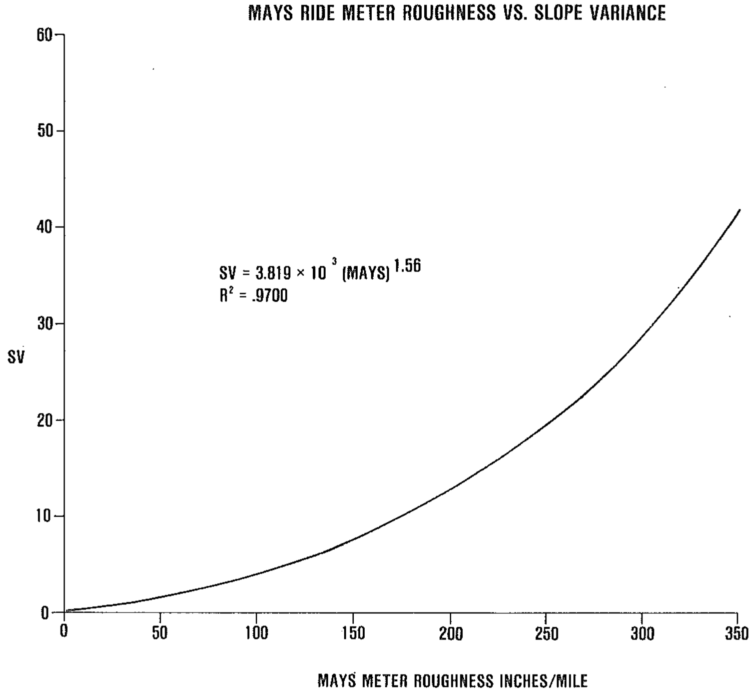
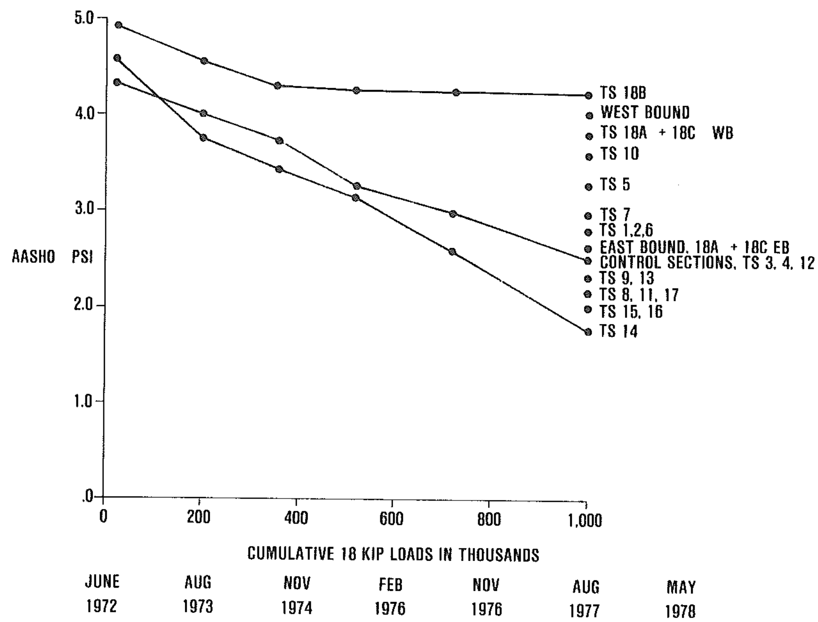


FIGURE 9

AASHO PRESENT SERVICEABILITY INDEX (PSI) VS. 18 KIP LOADS



With all the above information it was possible to examine various overlay design techniques to test their ability to predict actual performance and suggest alterations where necessary. In the 1972 AASHTO Interim guides (6) it is stated, "No standard or generally accepted procedure exists, (for overlay design) and state highway agencies are encouraged to develop procedures applicable to their specific conditions and requirements". Accordingly overlay approaches suggested by AASHTO and tried in Arizona were examined.

Modified AASHTO Equation

One approach was to use the AASHTO equation. That is, assign values to soil support, traffic, region and coefficients of all layers and solve for overlay thickness. The problem with this approach generally is assigning coefficient vaues for the combination of new overlay plus special treatment, such as heater scarification, asphalt rubber or low viscosity asphalt. To answer this problem the following approach was taken.

Given: Soil Support --- Set at 7.9 to give new A.C. overlay a value of .36, the design value.

Total 18kip to 2.5 psi --- Known from actual experience

Regional Factor --- Known, calculated according to present design procedure 1.7

Solve to get weighed SN

Set SN $a_1 D_1 \quad a_2 D_2 \quad a_3 D_3$

where

a_1D_1 surface overlay coefficient and thickness

a_2D_2 old AC and bound base coefficient and thickness

a_3D_3 subbase, select material or aggregate base

Known	Unknown
D_1	a_1 of new AC plus treatmentS

$a_2 = .17$

$a_3 = .06$

By using AASHTO Design Nomograph, Figure 2C, the a_1 coefficient was determined. Table 3 gives solutions ranked by decreasing new AC coefficient. It can be seen that treatments influenced results, therefore credits in terms of greater coefficient for treatment should be given in this process thus reducing the overlay needed.

6. "AASHTO Interim Guide for Design of Pavement Structures 1972," 1974, American Association of State Highway and Transportation Officials.

Treatment	TABLE 3	AASHTO Coefficient of New Overlay & Treatment
TS 10	200/300 Penetration	.92
TS 5	Asbestos	.81
TS 12	Petromat	.72
TS 1	Asphalt Rubber Seal Coat	.70
TS 3 & 4	Asphalt Rubber Under ACFC	.70
TS 9	Four Corners 120/150 Penetration	.70
TS 13	Fiberglass	.70
TS 11	Emulsion Treated Base	.66
TS 18 A+C	Heater Scarification + 1¼″ AC	.63
TS 8	40/50 Penetration	.47
TS 7	120/150 LA Basin Penetration	.44
TS 15	Petroset in Cracks	.42
TS 18B	Heater Scarification + 3″ AC	.41
TS 14	Petroset Flush	.38
TS 17	Reclamite Flush	.36
TS 16	Reclamite in Cracks	.36
Control Sections		.36
TS 6	2″ AC No ACFC	.20

Table 3 indicates that treatments from petroset flush upwards added structural value to the old AC, over and above that attributed to overlay thickness alone. If such a method were used, the new AC with a conventional overlay plus ACFC (control sections) would receive a structural coefficient of .36. An overlay with 200/300 penetration asphalt would allow the designer to increase the old AC structural coefficient from .36 to .92, thus reducing the required overlay thickness.

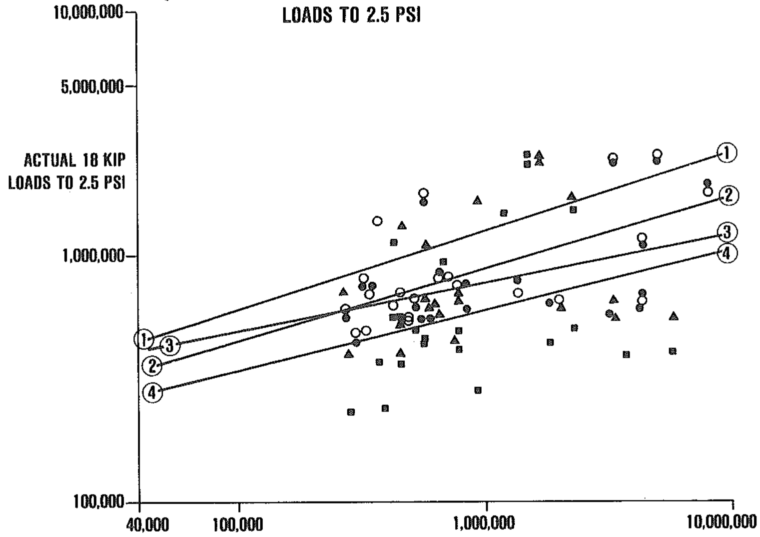
AASHTO Deflection Prediction of Pavement Life

In the AASHTO Road Test Report (4), it was shown that an initial fall or spring deflection was a good predictor of future PSI life. To test this process for overlays, the average dynaflect deflection for each test section tested after overlay in the spring and fall were converted to Benkelman Beam Deflections (first geophone deflection multiplied by 22.5). The calculated Benkelman Beam Deflection for spring or fall was used with the AASHTO Road Test (4) spring or fall equation to predict the number of remaining equivalent 18 kip loads to the failure PSI of 2.5. The deflection calculated remaining life was compared to the PSI remaining life (determined by plotting 18 kip vs. PSI, Figure 9) in Figure 10.

Figure 10 shows that the first spring deflection was the best predictor of actual overlay life. This is consistent with the AASHTO road test findings. It is interesting to note that as subsequest deflections were taken the agreement became poorer, indicating that initial deflections were more meaningful.

FIGURE 10

PREDICTED 18 KIP LIFE FROM AASHO ROAD TEST DEFLECTION EQUATIONS, FALL AND SPRING VS. ACTUAL 18 KIP LOADS TO 2.5 PSI



PREDICTED 18 KIP LOADS TO 2.5 PSI
EQUATION = $Y = A(x)^B$

LEGEND N = 22

LINE		R^2	A	B	
1	FALL OCT 1972	.2656	14720.	.3212	●
2	SPRING MAY 1973	.3635	17783.	.2845	○
3	SPRING MAY 1974	.1025	52553.	.1943	▲
4	SPRING MAY 1975	.0792	22243.	.2383	■

Arizona Proposed Modified AASHTO Deflection Prediction of Pavement Life

A suggested improvement to the above method would be to derive a set of functions which would more closely predict remaining life from a point estimate in time. To do this pavement performance was bracketed into sets for which a best fit line of 18 kips to 2.5 PSI versus dynaflect (first geophone converted to Benkelman beam; Multiplier 22.5) was determined.

The equation is $Y \cong AX^B$

$Y \cong$ PSI

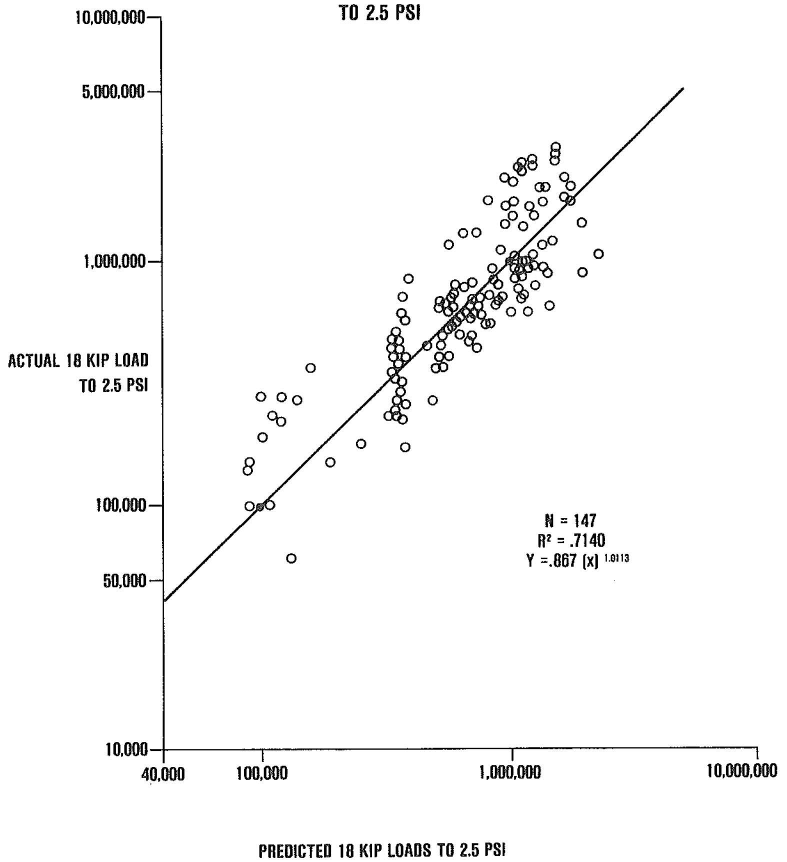
$X \cong$ Benekelman Beam Deflection

For each set actual measured dynaflect deflections were plotted versus remaining 18 kips to 2.5 PSI. A best fit line was calculated and the remaining life for each deflection was determined. A plot on Figure 11 shows the PSI deflection predicted life versus actual life and gives a correlation coefficient $R^2 \cong .7140$. Since at the time an overlay is to be designed it is possible to estimate the existing PSI and test the actual deflection, such an approach can be used to make a better prediction of remaining life.

PSI	N	R^2	A	B
4.0+	69	.2863	43,461.	- .9347
3.5 — 3.99	30	.3064	84,840.	- .6154
3.0 — 3.49	30	.0160	212,178.	- .1512
2.5 — 2.99	18	.1887	113.	-2.1160

FIGURE 11

PREDICTED 18 KIP LIFE BY ADOT METHOD VS. ACTUAL 18 KIP LOADS TO 2.5 PSI



California Overlay Deflection Method To Predict Remaining Life

Arizona has used two versions of this design procedure.

Deflection of the existing old road is measured. By knowing this deflection and thickness of the old road, it was possible to compute the overlay thickness needed to reach some desirable number of 18 kip loads to failure. In this case failure was vaguely defined as fatigue cracking failure. As can be seen, the existing pavement lasted considerably longer than estimated. Solutions for different percent cracking at failure were derived. As can be seen below the 10 percent cracking gave the best fit correlation value.

$Y = AX^B$

Y = Actual # of 18 kips to % cracking

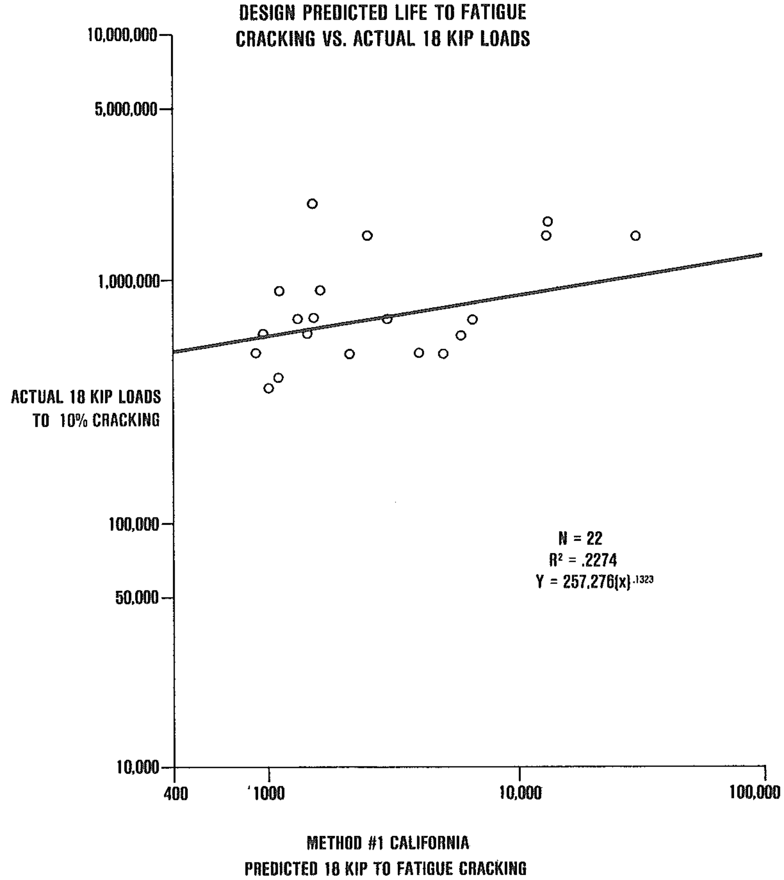
X = California calculated # of 18 kips to fatigue cracking

Figure 12 gives calculated expected life to 10 percent cracking estimated from this method versus actual life.

	N	R^2	A	B
1% cracking	22	.1270	152,000.	.1064
5% cracking	22	.1990	205,000.	.1281
10% cracking	22	.2274	257.000.	.1323
20% cracking	22	.1692	517,000.	.0886
30% cracking	22	.1148	743,000.	.0689
40% cracking	22	.0644	1,031,000.	.0506

FIGURE 12

METHOD #1 CALIFORNIA DEFLECTION DESIGN PREDICTED LIFE TO FATIGUE CRACKING VS. ACTUAL 18 KIP LOADS

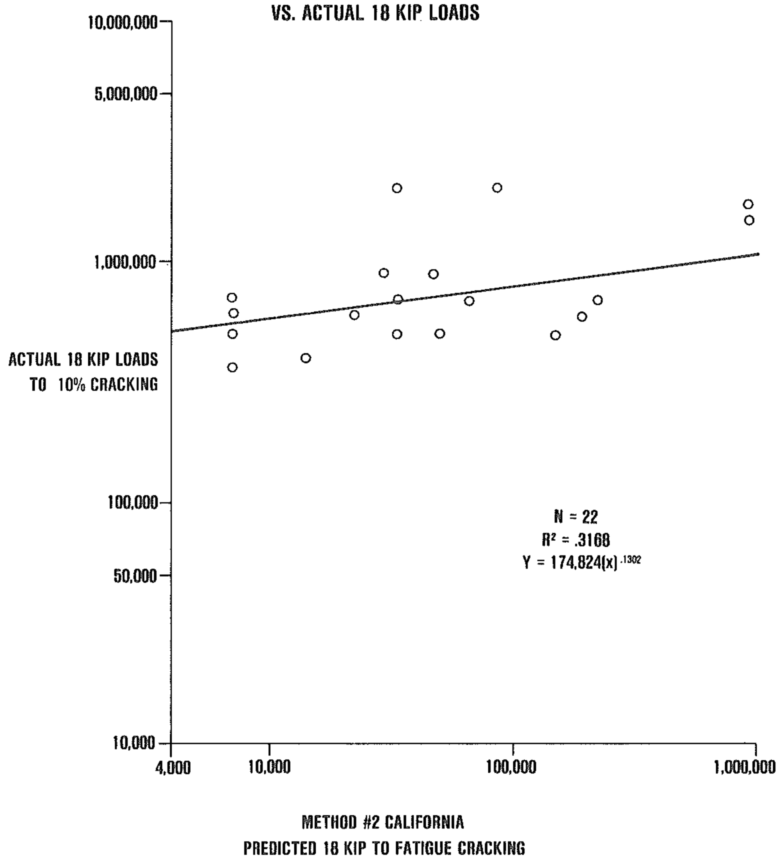


2. California in 1976 revised their design deflection chart, such that only the deflection before overlay was necessary to determine overlay thickness. Figure 13 shows the predicted or calculated number of 18 kips to failure versus actual. Again the differences are substantial. In essence the California method would predict much shorter lives for the overlays used, thus requiring by the California method much thicker overlays than necessary. In addition solutions at different percent cracking were derived and again the 10 percent cracking level gave the best fit.

$Y=AX^B$	N	R^2	A	B
1% cracking	22	.1752	112,00.	.1042
5% cracking	22	.2773	141,000.	.1261
10% cracking	22	.3168	175,000.	.1261
20% cracking	22	.2816	369,000.	.0943
30% cracking	22	.2042	549,000.	.0766
40% cracking	22	.1328	785,000.	.0606

FIGURE 13

METHOD #2 CALIFORNIA DEFLECTION DESIGN
PREDICTED LIFE TO. FATIGUE CRACKING
VS. ACTUAL 18 KIP LOADS



Arizona PMIS Overlay Method of Predicting Remaining Life

In 1976, Arizona was provided a report entitled, "Development of Framework for Pavement Management System For Arizona"(2), as well as a functional computer program, the purpose of this project was to devise a system to predict pavement performance of new and overlaid pavements in such a fashion that it could be used to determine an array of most economical designs. To start this program necessary information included:

Roughness before overlay
Deflection after overlay
Thickness of overlay
Region
Traffic

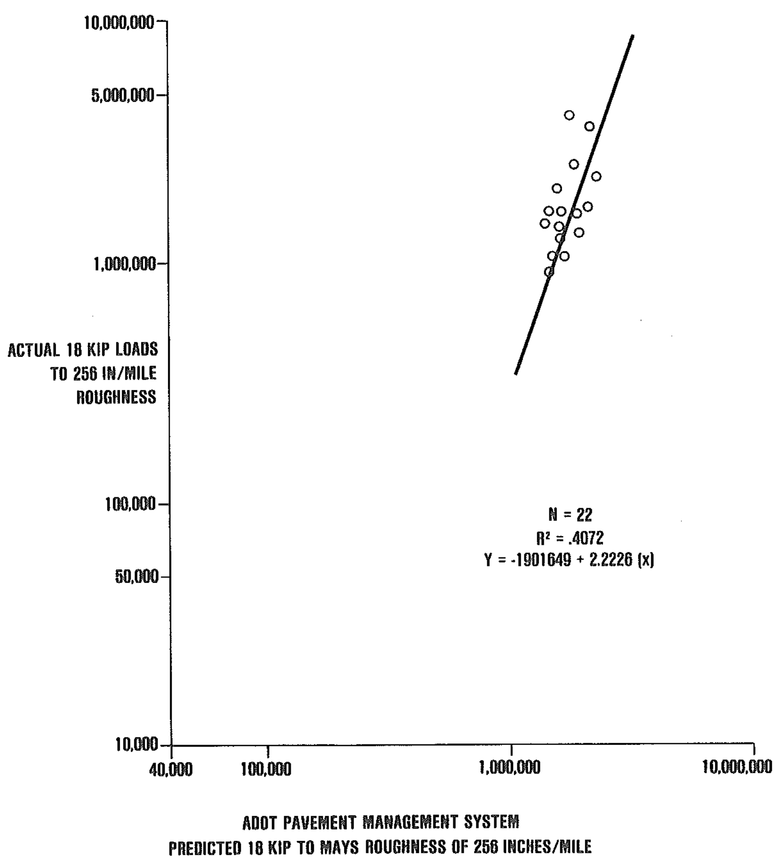
were input into the equations and the predicted performance curves in terms of roughness in inches/mile calculated. Figure 14 shows the predicted 18 kip loads to 256 inches/mile (a terminal roughness condition) versus actual loads. As can be seen this relationship is good, considering that the prediction equations were derived from a set of subjective values. The addition of objective field data to derive better prediction equations will improve and relationship shown on Figure 11.

Design Discussion

The previously examined design methods would indicate that a technique incorporating both a service condition and structural condition (deflection) will provide a better point estimate of future performance. Similarly a method which predicts future performance from past measured performance (pavement inventory) can also provide very good performance prediction. It is suggested that ADOT can adequately predict future performance by combining the two techniques. This would mean inventoring the highway for ride and cracking; however, when an overlay appeared necessary deflections would be taken before overlay to indicate the predicted life of an overlay. Following the overlay one additional set of deflections should be taken to determine an expected life estimate for the overlay, which would be matched against actual inventoried performance.

FIGURE 14

ADOT PAVEMENT MANAGEMENT SYSTEM PREDICTED 18 KIP TO TERMINAL ROUGHNESS VS. ACTUAL 18 KIP LOADS



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. As such Table 4 gives updated cost figures based on the 1978 project bids.

In the previous report (1) similar statistics were calculated, interestingly since 1975 the average cost of AC in-place has gone down about 10 percent. This is probably due to the extensive use of dryer drum plants in Arizona. The 1/2" ACFC, heater scarification and asphalt rubber have increased 25 percent, 50 percent and 50 percent respectively since 1975.

Using Table 4 and actual test section maintenance costs a cost performance statistic was determined, Table 5. To calculate this statistic the 1977 construction cost was added to the cumulative maintenance cost to 1977, then divided by the number of 18 kip loads in millions to a particular failure condition (10 percent cracking, 256 inches of roughness or 2.5 PSI). The cumulative maintenance is divided into two parts, routine maintenance and seal coat (or fog seal). Routine maintenance involves activities such as pavement dig out and patching, pothole patching, crack sealing and state maintenance seal coating. The seal coat in this case was a contract asphalt rubber seal coat. Since this is a cracking study the cost performance index is ranked by cracking, that is the LA Basin 200/300 had the lowest cost performance index of $1.55 per 1,000,000 18 kip loads in cracking whereas LA Basin 40/50 pen cost $8.50 per 1,000,000 18 kip loads. The 40/50 pen costs more because it needed more maintenance and it lasted such a few number of 18 kip repetitions to 10 percent cracking. The costs for ride and PSI can be substantially different because the number of repetition to failure is different. In general costs to ride or PSI failure are smaller or put another way cracking failure occurs sooner than roughness. A similar finding for new construction is contained in the AAPT report (5). It can be seen that depending upon the relative weight given to each performance measure the cost performance index can vary substantially, such that for reflective cracking control the following treatments are most economically effective.

200/300 penetration
Asphalt rubber between AC and ACFC
Asbestos
Heater scarification with 3", 1-1/2" or 1-1/4" AC

For ride control the following treatments are most economically effective:

200/300 penetration Heater scarification with 3" AC
Asbestos
120/150 penetration
Asphalt rubber flush-in
2" AC no ACFC

Generally for crack control flexibility is most important whereas for ride control, bulk properties and thickness are most important.

TABLE 4
1978 Project Cost Summary

Subject-Classification	N	Cost per square yard Average	High	Low
1″ of AC in-place	13	$ .700	.861	.504
½″ of ACFC in-place	10	.720	1.205	.432
Heater scarification plus reclamite	13	.522	.706	.386
Asphalt rubber plus chips	8	1.121	1.452	.830

N = number of project bids considered

TABLE 5

COST PERFORMANCE INDEX
COST PER SQUARE YARD
DIVIDED BY PERFORMANCE

		MAINTENANCE		COST PERFORMANCE INDEX		
TEST SECTION	1977 CONSTRUCTION	ROUTINE	SEAL COAT	CRACKING	RIDE	PSI
#10 LA BASIN 200/300	1.56	.05	.71	1.55	.63	1.16
# 3 & 4 ASPHALT RUBBER BETWEEN A.C. ACFC	2.72	.02	.71	1.73	2.65	3.83
#5 ASBESTOS	2.03	.04	.71	1.85	1.11	1.96
#18C HEATER SCARIFICATION 3" AC, ½" ACFC	3.34	.07	.05	2.32	.98	1.30
# 7 LA BASIN 120/150	1.56	.22	.71	2.77	1.25	1.54
#1 ASPHALT RUBBER CHIP SEAL ON AC	2.00	.12	.71	3.14	1.29	3.18
#18A & B PLUS RECLAMITE HEATER SCARIFICATION	2.20	.27	.71	3.19	1.89	3.25
CONTROL 1¼"AC, ½"ACFC	1.60	.36	.71	3.87	1.79	2.84
HEATER SCARIFICATION #2 PLUS PETROSET	2.12	.39	.71	4.60	2.05	3.07
RECLAMITE AND #15, 16, 17 PETROSET FLUSH	1.69	.54	.71	4.90	2.47	3.45
#18B EAST BOUND STRIPPING AC	2.29	.47	.71	5.03	2.17	3.94
#14 PETROSET FLUSH ON NEW AC	1.70	.87	.71	5.47	3.57	4.56
#6 2" AC NO ACFC	1.40	.74	.71	5.70	1.44	2.88
#13 FIBERGLASS	2.71	.30	.71	6.20	2.74	4.00
#11 EMULSION TREATED BASE	1.94	.76	.71	6.82	2.80	4.43
#12 PETROMAT	2.65	.43	.71	7.58	2.40	3.64
#9 FOUR CORNERS 120/150 PEN	1.56	.90	.71	7.93	2.30	3.69
#8 LA BASIN 40/50 PEN	1.56	.79	.71	8.50	2.91	4.25

CONCLUSIONS

It has been demonstrated that thin overlays plus special treatments can control cracking while providing more than satisfactory ride and rutting performance. Such thin overlays plus treatment are economical by any measure. The mechanism by which these treatments perform can be summarized as follows.

1. Stress absorbing membrane interlayer SAMI. Use of asphalt rubber between the new AC and ACFC acts as a crack tip retarder since it has such a low modulus of elasticity (estimated at about 5000 psi). The placement of this layer at or near the top of overlay delays reflective cracks; however, an uncomfortable amount of shoving can occur, thus leading to a rough ride. Such a condition became apparent after the 1975 asphalt rubber seal coat was placed over the ACFC. This seal coat was not necessary; however, its placement helped verify the point at which flexibility can give way to instability. To be consistent with fracture mechanics theory (7) it is suggested the asphalt rubber layer be placed on top of the old AC with the new AC on top of it. In this way the overlay structure would comply with the Texas report (6), quoting the Conclusion 1 in full.

   "1. The best overlay design to reduce the appearance of cracking is, as shown in Figure 20, namely:

      a) a thin layer with soft asphalt (low n) and low modulus of elasticity to serve as a stress relieving medium overlaid by,

      b) a layer with soft asphalt (low n) and a high modulus of elasticity.

   Although this arrangement will hasten the propagation of unseen cracks through the surface of old pavement, it will slow them down considerably when they reach the surface and contact the underside of the stress-relieving layer." End of quote.

2. Mechanical rearrangement of the old AC crack pattern, heater scarification. This process which is akin to in-place recycling, remolds 3/4 to 1 inch of old AC into a material similar to a new AC. In so doing, it shortens the existing crack length by 3/4 to 1 inch. This shortening of crack length can and does substantially reduce reflective cracking as demonstrated in the Texas Transportation Institute report (6), which examines reflective cracking using fracture mechanics.

3. Low viscosity asphalt in the AC or over asphalted AC,200/300 pen and asbestos sections. Both the 200/300 pen and asbestos sections substantially alter the elastic modulus of the AC thus altering certain fatigue parameters which reduce the crack tip stress intensity value. In some ways this approach is akin to the asphalt-rubber interlayer, except the layer now becomes the entire AC overlay.

With regard to overlay procedures to predict future life it appears that those methods which incorporate terms for both performance and support (deflection) give more realistic results than just deflection alone.

Cost considerations show how important it is to select the correct overlay design. If the wrong design were built it could easily triple the long-term costs of the overlay. Again the Pavement Management System calculates a future worth or cost performance value such that overlay designs can be arrayed in terms of dollars. In this way expensive, poor performing designs can be avoided.

7. Carpenter, S.H., Chang, H. and Lytton, R.L., "Prediction of Thermal Reflection Cracking in West Texas," March 1976, Texas Transportation Institute.

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 relfective cracking in the overlays when placed over severely cracked bituminous pavements.

This report represents the culmination of over seven 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:

   Asphalt rubber membrane seal coat under ACFC
   Asbestos plus 3 percent asphalt
   Heater scarification with reclamite.
   Asphalt rubber membrane flushed into asphaltic concrete overlay
   200/300 penetration asphalt

2. One of the above treatments should be used for thin overlays (4 inches or less) placed over badly cracked pavements. Considerations are as follows:

   a. 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. The asphalt rubber membrane should be placed on top of the old AC as this location reduces the crack tip stress intensity, thus increasing the time it takes for the crack to reach the top of the AC. In addition this location should reduce the likelihood of rutting and shoving thus producing a superior riding surface.

      The asphalt rubber seal coat may be placed on the top of the AC overlay, although roughness and shoving may be increased.

   b. Scarification should be to a minimum depth of 3/4 inches. Deeper depths of scarification are encouraged since this shortens the length of the existing crack, thus increasing the length of time necessary for the crack to come to the surface.

   c. The lowest viscosity asphalt with the slowest aging characteristics is recommended. Unfortunately, as of this report, an asphalt grade of suitably low viscosity for regions with a freezing index 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.

   d. The use of an overasphalted fiber reinforced overlay is encouraged; however, such a method should only be used in conjunction with an ACFC or other suitable anti-skid surface.

3. The design of overlays should incorporate a means by which performance, materials characteristics and costs are used to determine the appropriate design.

In the previous report (1) two other recommendations were made and are reiterated here:

4. 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.

5. 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.

Several of the above recommendations were contained in the first report. At this time recommendations 1, 2a, 2b and 5 have been substantially implemented. It is strongly recommended that all other recommendations be implemented, particularly 2c and 3.

Appendix A

TABLE 1A

Percent Reflective Cracking, Minnetonka-East

Cracking Analysis

Location	Test Section	% Cracking Before Overlay	% Reflected Cracking * (Base Set 1971)						
		1971	1972	1973	1974	1975	1976	1977	1978
East Bound		TS #2							
285+00 - 25	H&S Petroset	1.7	0	0	0	0	17.6	0	0
292+50 - 75		15.1	0	0	0	7.9	0	0	0
293+50 - 75		12.9	0	0	0	0	0	0	1.1
		TS #18A							
229+75 - 230 EB	H & S	9.6	0	0	0	0	0	0	5.0
254+75 - 255 EB	Reclamite	7.3	0	0	0	0	0	0	0
266+75 - 267 EB	1-1/4" AC, 1/2" ACFC	15.0	0	0	0	13.3	20.7	32.7	13.3
239+75 - 240 WB		8.1	0	0	0	21.0	77.8	86.4	86.4
		TS #18C							
588+00 - 25 EB	H & S Reclamite	10.2	0	0	0	0	0	0	9.8
639+75 - 640 EB	1-1/2" AC, 1/2" ACFC	24.0	0	0	0	0	0	21.7	31.3
649+75 - 650 EB		15.5	0	0	9.0	12.9	46.5	18.7	64.5
599+75 - 600 WB		13.0	0	0	3.8	3.8	3.8	3.8	3.8
		TS #18B							
329+75 - 330 WB	H & S Reclamite	7.1	0	0	0	22.5	22.5	23.9	24.1
499+75 - 500 WB	3" AC, 1/2" ACFC	26.3	0	0	0	4.9	4.9	4.9	4.9
EB									
283+25 - 50	Control	11.0	9.1	14.5	7.3	44.5	38.2	9.1	0
284+50 - 75	1-1/4" AC, 1/2" ACFC	10.8	17.6	19.4	19.4	42.6	25.0	0	0
295+75 - 296		11.8	15.3	11.9	13.6	32.6	21.2	0	19.6
299+75 - 300		11.7	0	0	0	0	0	0	0
498+00 - 25		14.0	0	14.3	35.0	39.3	16.4	19.3	7.1
499+00 - 25		13.0	0	0	0	6.2	0	7.7	0
499+25 - 50		12.8	0	0	0	3.9	0	0	0
EB									
604+75 - 605	Control 1-1/2" AC, 1/2" ACFC	16.7	0	0	0	0	0	0	0

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

TABLE 1A CONTINUED

Location	Test Section	% Cracking Before Overlay	% Reflected Cracking * (Base Set 1972)						
		1971	1972	1973	1974	1975	1976	1977	1978
WB									
271+75 - 272	Control	8.4	0	14.3	21.4	36.9	36.9	50.2	60.7
401+75 - 402	3" AC, 1/2" ACFC	13.1	0	0	0	0	0	13.0	53.4
		TS #1							
302+75 - 303	Rubberized Asphalt	11.6	16.0	11.9	25.6	26.3	0	14.4	14.4
309+25 - 50	seal coat with precoated ships	15.5	21.4	0	0	12.1	4.7	11.2	11.2
		TS #3							
310+25 - 5	Rubberized seal	19.1	30.2	0	0	7.9	0	0	1.7
317+75 - 318	coat under ACFC	13.8	21.8	0	0	0	0	0	0
319+00 - 25		12.2	18.3	0	0	10.4	0	0	0
		TS #4							
325+25 - 50	Rubberized seal	14.8	32.0	0	2.5	5.9	0	1.9	1.9
326+50 - 75	coat under ACFC	12.6	27.2	0	0	0	0	0	0
334+00 - 25		12.0	11.1	0	0	0	7.2	7.2	9.0
		TS #5							
335+00 - 25	Asbestos added	9.4	12.1	0	0	16.5	0	0	1.2
337+00 - 25	to AC	12.1	32.7	0	0	9.5	1.5	2.1	3.0
341+50 - 75		9.5	10.4	0	0	13.5	5.8	9.6	13.5
		TS #6							
353+50 - 75	No ACFC	7.9	8.5	0	11.8	38.8	43.5	69.4	88.6
358+75 - 359	AC 2"	9.8	11.0	0	34.5	90.9	9.1	40.0	61.2
362+50 - 75	Thick	9.5	9.0	0	35.6	118.9	8.9	81.1	84.2
368+00 - 25		19.6	15.6	0	32.7	49.4	19.2	44.9	40.8
368+75 - 369		32.5	31.8	0	17.6	22.3	2.5	5.7	3.1
		TS #7							
371+00 - 25	120/150 Pen	30.3	43.5	2.3	4.6	16.3	16.6	32.2	3.3
372+00 - 25	LA Basin	18.2	32.2	0	1.2	12.7	9.6	23.6	54.9
375+00 - 25		28.2	24.5	0	0	13.9	2.0	26.1	24.8
		TS #8							
386+75 - 387	40/50 Pen	23.1	31.1	1.6	8.4	22.5	11.3	11.9	34.6
392+50 - 75	LA Basin	42.0	64.1	5.6	24.7	24.6	16.8	22.8	7.1
394+75 - 395		31.7	43.0	0	0	11.9	9.1	32.1	31.5
		TS #9							
397+50 - 75	120/150 Pen	28.5	35.0	4.9	21.1	24.9	2.3	2.3	7.0
399+25 - 50	Four Corners	15.2	14.7	0	8.2	19.7	23.1	2.0	0
404+00 - 25		12.8	11.7	0	0	10.3	33.3	7.7	0

TABLE 1A CONTINUED

Location	Test Section	% Cracking Before Overlay	% Reflected Cracking * (Base Set 1972)						
		1971	1972	1973	1974	1975	1976	1977	1978
		TS #10							
East Bound									
410+00 - 25	200/300 Pen	25.5	25.7	0	0	10.9	12.1	16.0	21.3
412+74 - 413	LA Basin	24.8	20.3	0	0	2.0	0	18.0	19.0
416+00 - 25		12.3	10.0	0	0	10.0	0	14.0	8.0
		TS #11							
420+50 - 75		25.2	34.1	0	4.7	12.6	4.4	6.5	0
421+75 - 422	ETB	19.5	20.0	0	3.0	14.5	4.0	4.0	0
426+00 - 25		44.0	46.1	0	0	2.4	2.2	2.0	0
427+25 - 50		26.8	34.1	5.9	24.3	28.2	6.7	0	0
		TS #12							
435+00 - 25	Petromat	43.9	44.4	0	0	9.5	7.2	0	2.3
437+75 - 438		30.0	32.3	0	0	14.9	16.7	22.9	10.0
		TS #13							
440+50 - 75		30.2	29.9	0	0	8.0	0	0	0
440+75 - 441	Fiberglass		30.4	0	1.3	5.3	0	0	3.3
441+75 - 442			11.1	0	0	0	22.5	40.5	9.0
443+75 - 444			30.5	0	0	5.6	10.5	9.8	3.3
		TS #14							
452+00 - 25	Petroset	32.4	31.0	5.8	11.9	20.6	0	0	0
453+50 - 75	Flushed into	44.0	48.9	2.5	8.6	14.3	8.6	0	0
455+75 - 456	Overlay	32.7	38.1	5.0	7.3	13.4	5.2	0	0
		TS #15							
460+25 - 50	Petroset in	25.2	27.0	0	0	14.1	18.5	0	4.0
465+75 - 466	cracks of	37.5	41.5	0	7.0	10.1	11.1	13.5	22.2
467+75 - 468	AC	30.6	40.9	0	2.0	12.5	16.5	13.0	7.3
		TS #16							
478+75 - 479	Reclamite	23.2	31.7	0	0	6.3	0	0	6.3
479+50 - 75	in cracks of	22.2	20.5	8.8	27.3	29.8	0	0	9.8
483+25 - 50	old AC	15.5	26.1	10.0	16.5	20.3	0	0	7.7
		TS #17							
487+75 - 488	Reclamite Flush	12.8	15.8	0	0	5.7	0	0	0
490+75 - 491	of old AC	16.1	23.7	0	7.6	20.3	0	0	0
491+00 - 25		20.4	17.3	0	0	20.2	0	0	0

TABLE 1A CONTINUED

Location	Test Section	% Cracking Before Overlay 1971	% Reflected Cracking * (Base Set 1972) 1972	1973	1974	1975	1976	1977	1978
320+50 - 75		12.3	25.2	0	0	3.9	3.9	8.6	16.9
322+75 - 323	Control	17.7	25.3	0	0	11.9	0	0	0
346+50 - 75	1-1/4" AC, 1/2" ACFC	16.1	34.1	0	0	3.2	0	.5	3.5
349+50 - 75		10.0	19.4	0	0	0	4.1	5.2	12.3
380+75 - 381		35.7	49.2	0	0	5.1	7.5	14.8	25.3
383+25 - 50		40.7	54.2	0	0	6.6	14.6	23.2	27.7
407+75 - 408		26.5	28.5	0	0	6.7	12.6	23.9	36.1
409+00 - 25		21.1	43.0	0	0	8.4	9.6	30.0	36.9
433+75 - 444		18.4	19.0	0	5.3	28.4	0	0	10.5
448+25 - 50		34.4	39.4	5.6	8.9	12.4	0	0	0
449+50 - 75		23.1	23.7	12.2	15.2	36.7	0	0	0
470+25 - 50		14.3	16.0	0	0	15.6	19.4	38.1	38.3
473+00 - 25		20.0	22.0	0	0	13.6	22.3	21.8	70.2

TABLE 2A

Percent Travel Lane Area Patched
Minnetonka-East

Patching Analysis

Location	Test Section	% Cracking Before Overlay 1971	% Travel Lane Area Patched 1972	1973	1974	1975	1976	1977	1978
		TS #2							
East Bound									
285+00 - 25	H&S Petroset	1.7	0	0	0	0	0	0	100
292+50 - 75		15.1	0	0	0	0	0	100	100
293+50 - 75		12.9	0	0	0	0	0	0	50
		TS #18A							
229+75 - 230 EB	H & S	9.6	0	0	0	0	0	0	0
254+75 - 255 EB	Reclamite	7.3	0	0	0	0	0	25	100
266+75 - 267 EB	1-1/4" AC, 1/2" ACFC	15.0	0	0	0	0	0	0	100
239+75 - 240 WB		8.1	0	0	0	0	0	0	0
		TS #18C							
588+00 - 25 EB	H & S Reclamite	10.2	0	0	0	0	0	0	0
639+75 - 640 EB	1-1/2" AC, 1/2" ACFC	24.0	0	0	0	0	0	0	10
649+75 - 650 EB		15.5	0	0	0	0	0	0	10
599+75 - 600 WB		13.0	0	0	0	0	0	0	10
		TS #18B							
329+75 - 330 WB	H & S Reclamite	7.1	0	0	0	0	0	0	0
499+75 - 500 WB	3" AC, 1/2" ACFC	26.3	0	0	0	0	0	0	0
EB									
283+25 - 50	Control	11.0	0	0	0	0	0	0	100
284+50 - 75	1-1/4" AC, 1/2" ACFC	10.8	0	0	0	0	0	0	100
295+75 - 296		11.8	0	0	0	0	0	100	100
299+75 - 300		11.7	0	0	0	0	0	0	10
498+00 - 25		14.0	0	0	0	0	0	0	100
499+00 - 25		13.0	0	0	0	0	0	10	100
499+25 - 50		12.8	0	0	0	0	0	20	100
EB									
604+75 - 605	Control 1-1/2" AC, 1/2" ACFC	16.7	0	0	1	1	5	5	80

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

TABLE 2A CONTINUED

Location	Test Section	% Cracking Before Overlay 1971	% Travel Lane Area Patched 1972	1973	1974	1975	1976	1977	1978
WB									
271+75 - 272	Control	8.4	0	0	0	0	0	0	0
401+75 - 402	3" AC, 1/2" ACFC	13.1	0	0	0	0	0	0	0
		TS #1							
302+75 - 303	Rubberized Asphalt	11.6	16.0	0	0	0	0	0	0
309+25 - 50	seal coat with precoated ships	15.5	21.4	0	0	0	0	0	0
		TS #3							
310+25 - 5	Rubberized seal	19.1	30.2	0	0	0	0	0	0
317+75 - 318	coat under ACFC	13.8	21.8	0	0	0	0	0	0
319+00 - 25		12.2	18.3	0	0	0	0	0	0
		TS #4							
325+25 - 50	Rubberized seal	14.8	32.0	0	0	0	0	0	0
326+50 - 75	coat under ACFC	12.6	27.2	0	0	0	0	0	0
334+00 - 25		12.0	11.1	0	0	0	0	0	0
		TS #5							
335+00 - 25	Asbestos added	9.4	12.1	0	0	0	0	0	0
337+00 - 25	to AC	12.1	32.7	0	0	0	0	0	0
341+50 - 75		9.5	10.4	0	0	0	0	0	0
		TS #6							
353+50 - 75	No ACFC	7.9	8.5	0	0	0	0	0	0
358+75 - 359	AC 2"	9.8	11.0	0	0	0	0	0	20
362+50 - 75	Thick	9.5	9.0	0	0	0	0	0	0
368+00 - 25		19.6	15.6	0	0	0	0	100	100
368+75 - 369		32.5	31.8	0	0	0	0	10	100
		TS #7							
371+00 - 25	120/150 Pen	30.3	43.5	0	0	0	0	0	0
372+00 - 25	LA Basin	18.2	32.2	0	0	0	0	0	1
375+00 - 25		28.2	24.5	0	0	0	0	0	0
		TS #8							
386+75 - 387	40/50 Pen	23.1	31.1	0	0	0	75	100	100
392+50 - 75	LA Basin	42.0	64.1	0	0	40	40	40	100
394+75 - 395		31.7	43.0	0	0	0	0	0	100
		TS #9							
397+50 - 75	120/150 Pen	28.5	35.0	0	0	0	0	100	100
399+25 - 50	Four Corners	15.2	14.7	0	0	0	0	100	100
404+00 - 25		12.8	11.7	0	0	0	70	100	100

TABLE 2A CONTINUED

Location	Test Section	% Cracking Before Overlay 1971	% Travel lane Area Patched 1972	1973	1974	1975	1976	1977	1978
		TS #10							
East Bound									
410+00 - 25	200/300 Pen	25.5	25.7	0	0	0	0	0	0
412+74 - 413	LA Basin	24.8	20.3	0	0	0	0	0	0
416+00 - 25		12.3	10.0	0	0	0	0	0	0
		TS #11							
420+50 - 75		25.2	34.1	0	0	0	0	0	100
421+75 - 422	ETB	19.5	20.0	0	0	0	10	20	100
426+00 - 25		44.0	46.1	0	0	0	0	100	100
427+25 - 50		26.8	34.1	0	50	50	100	100	100
		TS #12							
435+00 - 25	Petromat	43.9	44.4	0	0	0	100	100	100
437+75 - 438		30.0	32.3	0	0	0	0	0	0
		TS #13							
440+50 - 75		30.2	29.9	0	0	1	100	100	100
440+75 - 441	Fiberglass		30.4	0	0	0	100	100	100
441+75 - 442			11.1	0	0	0	0	0	0
443+75 - 444			30.5	0	0	0	0	70	90
		TS #14							
452+00 - 25	Petroset	32.4	31.0	0	0	0	100	100	100
453+50 - 75	Flushed into	44.0	48.9	0	0	0	70	100	100
455+75 - 456	Overlay	32.7	38.1	0	0	0	50	100	100
		TS #15							
460+25 - 50	Petroset in	25.2	27.0	0	0	0	0	100	100
465+75 - 466	cracks of	37.5	41.5	0	0	0	0	0	0
467+75 - 468	AC	30.6	40.9	0	0	0	0	0	0
		TS #16							
478+75 - 479	Reclamite	23.2	31.7	0	0	0	100	100	100
479+50 - 75	in cracks of	22.2	20.5	0	0	0	100	100	100
483+25 - 50	old AC	15.5	26.1	0	0	0	100	100	100
		TS #17							
487+75 - 488	Reclamite Flush	12.8	15.8	0	0	0	100	100	100
490+75 - 491	of old AC	16.1	23.7	0	0	0	100	100	100
491+00 - 25		20.4	17.3	0	0	0	100	100	100

TABLE 2A CONTINUED

Location	Test Section	% Cracking Before Overlay	% Travel Lane Area Patched						
		1971	1972	1973	1974	1975	1976	1977	1978
320+50 - 75		12.3	25.2	0	0	0	0	0	0
322+75 - 323	Control	17.7	25.3	0	0	0	0	0	0
346+50 - 75	1-1/4" AC, 1/2" ACFC	16.1	34.1	0	0	0	0	0	0
349+50 - 75		10.0	19.4	0	0	0	0	0	0
380+75 - 381		35.7	49.2	0	0	0	0	0	0
383+25 - 50		40.7	54.2	0	0	0	0	0	0
407+75 - 408		26.5	28.5	0	0	0	0	0	0
409+00 - 25		21.1	43.0	0	0	0	0	0	0
433+75 - 444		18.4	19.0	0	0	5	100	100	100
448+25 - 50		34.4	39.4	0	0	40	100	100	100
449+50 - 75		23.1	23.7	0	0	0	100	100	100
470+25 - 50		14.3	16.0	0	0	0	0	0	0
473+00 - 25		20.0	22.0	0	0	0	0	0	0

TABLE 3A
RANKING OF TEST SECTIONS

1978

% REFLECTIVE CRACKING
NO MAINTENANCE PATCHING

TEST SECTION #	%
#3&4 Asphalt Rubber Under ACFC	2.1
#5 Asbestos	5.9
#18A Heater Scarification plus Reclamite	7.4
#1 Asphalt Rubber Flush-In	12.8
#10 200/300 Penetration	16.1
Control Sections	27.0

*Given an adjacent test section and control section

TS	CONTROL

using the sum of the 1978 % reflective cracking and patching for the test section and the control section, a ratio of test section to control was calculated.

$$\text{RATIO} = \frac{\text{TS \% Reflective Cracking + Patching}}{\text{Control \% Cracking + Patching}}$$

Ratios expressed as percent were calculated for each TS and are shown on adjacent table. A low % means the section has performed better than its adjacent control. A % above 100. means the TS has performed worse than its neighbor.

1978

*RATIO OF % REFLECTIVE CRACKING PLUS PATCHING OF TEST SECTION COMPARED TO ADJACENT CONTROL SECTION

TEST SECTION #	%
#3 Asphalt Rubber Under ACFC	7.1
#10 200/300 Penetration	18.6
#1 Asphalt Rubber Flush-In	21.4
#4 Asphalt Rubber Under ACFC	42.9
#12 Petromat	50.8
#2 Heater Scarification Plus Petroset	52.2
#18A Heater Scarification Plus Reclamite	73.1
#5 Asbestos	74.7
#13 Fiberglass	76.9
#15 Petroset in Cracks	81.4
#11 Emulsion Treated Base	90.5
#17 Reclamite Flush	97.7
#14 Petroset Flush	100.0
#7 120/150 LA Pen.	104.5
#9 120/150 Four Corners	118.3
#16 Reclamite In Cracks	198.7
#8 40/50 Pen	469.4
#6 2" AC No ACFC	1260.8

TABLE 4A

MAYS-RIDE METER

CORRECTED INCHES/MILES

Roughness (Inches)

Test Section	Before Overlay	After Overlay									
	4/11/72	7/11/72	2/26/73	7/31/73	10/10/73	2/21/74	5/16/74	5/21/75	8/19/76	12/1/76	8/18/77
T.S. 10 200/300 Pen	123	22	34	37	30	40	46	29	62	40	85
T.S. 12 Petromat	193	40	27	44	37	40	35	59	137	128	180
T.S. 7 120/150 Pen LA	132	29	37	54	37	44	59	83	66	57	98
T.S. 9 120/150 Pen 4 C.	138	13	30	46	35	53	62	80	156	140	185
T.S. 2 Scarification	149	25	27	30	34	33	40	92	161	121	149
T.S. 5 Asbestos	130	44	50	51	51	51	62	92	99	64	125
T.S. 13 Fiberglass	185	44	37	51	34	48	53	92	180	142	189
T.S. 17 Reclamite Flush	178	20	25	39	39	51	66	92	125	123	203
T.S. 16 Reclamite in Cracks	134	20	51	52	57	66	83	100	192	123	251
T.S. 15 Petroset in Cracks	178	11	34	54	59	64	72	101	158	136	229
Control Section	176	42	45	58	50	66	79	121	137	126	183
T.S. 14 Petroset Flush	178	29	56	74	63	83	97	121	182	180	308
T.S. ACFC over rubberized 3&4	149	40	56	80	76	115	91	131	174	166	198
T.S. 8 40/50 Pen.	132	26	32	47	37	72	97	130	211	189	232
T.S. 6 2" AC no ACFC	128	35	67	80	71	88	109	130	104	97	154
T.S. 1 Rubberized Seal Coat	149		110	132	100	123	119	163	109	114	154
T.S. 11 Emulsion Treated Base	149	57	74	115	105	123	127	171	189	201	206

TABLE 5A

RUT DEPTH IN INCHES

YEAR

TEST SECTION	1971	1972	1973	1974	1975	1976	1977	1978
TS #1 Asphalt Rubber Seal	1.00	.00	.12	.23	.36	.40	.44	.50
TS #2 HS & Petroset	.63	.00	.04	.09	.13	.17	.21	.20
TS #3 & 4 Asphalt Rubber	1.13	.00	.07	.15	.22	.30	.35	.40
TS #5 Asbestos	.63	.00	.08	.11	.15	.16	.17	.17
TS #6 2" AC NO ACFC	.58	.00	.08	.17	.25	.27	.31	.33
TS #7 LA 120/150	.94	.00	.13	.26	.20	.25	.31	.30
TS #8 LA 40/50	1.25	.00	.10	.20	.29	.30	.32	.33
TS #9 120/150 Four C	.50	.00	.09	.17	.26	.30	.36	.40
TS #10 LA 200/300	.88	.00	.04	.09	.13	.15	.20	.20
TS #11 ETB	1.00	.00	.07	.14	.21	.25	.30	.40
TS #12 Petromat	.38	.00	.04	.09	.13	.17	.22	.30
TS #13 Fiberglass	.38	.00	.07	.14	.20	.27	.33	.40
TS #14 Petroset	.50	.00	.08	.17	.25	.30	.33	.44
TS #15 Petroset	.25	.00	.07	.14	.20	.30	.40	.50
TS #16 Reclamite	.50	.00	.07	.14	.20	.22	.31	.40
TS #17 Reclamite	.25	.00	.05	.10	.15	.20	.25	.40
TS #18B HS & 3" AC, ACFC	.43	.00	.07	.13	.16	.16	.18	.20
East Bound	.53	.00	.05	.10	.19	.26	.32	.34
West Bound	.58	.00	.06	.11	.19	.19	.21	.25

TABLE 6A
DEFLECTION TEST RESULTS

Values Based on Percent Change In Individual Deflections

Date Of Test And Air Temperature	Average Deflection Mils	(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, 74 69°F	1.74	78	120	34	271	60	60	18
June, 75 69°F	1.74	78	120	34	290	52	64	14
Feb., 76 62°F	1.38	77	95	30	208	50	32	45
July, 76 98°F	1.69	76	117	32	219	70	57	19
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
Feb., 76 62°F	.89	84	91	27	175	40	27	57
July, 76 98°F	1.47	84	139	43	250	59	68	16

TABLE 7A

AVERAGE DEFLECTION OF EACH TEST SECTION

FIRST GEOPHONE DEFLECTION IN MILS OF AN INCH

TABLE VALUE OF 1.00 = .001"

.001" Dynaflect = .0225 Benkelman Beam

Test Section	n # of Tests	June 1971 100°F	Aug. 1971 80°F	June 1972 76°F	Oct. 1972 54°F	May 1973 74°F	Jan. 1974 46°F	May 1974 69°F	June 1975 69°F	Feb. 1976 62°F	July 1976 98°F
T.S. 1 Asphalt-Rubber Seal	3	1.07	.91	1.15	1.06	1.30	1.14	.92	.94	.86	1.18
T.S. 2 Scarification W/Petroset	3	1.72	--	1.25	1.26	1.81	2.21	1.72	2.12	1.53	2.56
T.S. 3 & 4 Asphalt-Rubber Under ACFC	6	1.71	1.57	1.36	1.43	1.98	1.94	1.79	1.72	1.34	1.79
T.S. 5 Asbestos	4	.99	.95	.75	.76	1.04	1.10	.94	.88	.92	1.11
T.S. 6 2" AC No ACFC	7	1.36	1.06	.95	1.35	1.74	1.87	1.12	1.24	1.18	1.79
T.S. 7 LA 120/150 Pen	3	1.73	1.61	1.32	1.48	2.18	2.33	1.94	2.11	1.74	1.90
T.S. 8 LA 40/50 Pen	3	1.91	1.60	1.40	1.40	2.26	2.29	2.06	2.37	1.74	1.93
T.S. 9 120/150 Pen 4C	4	1.84	1.61	1.55	1.40	2.10	2.11	1.88	2.19	1.96	1.94
T.S. 10 LA 200/300 Pen	4	1.49	1.20	1.13	1.06	1.91	1.52	1.64	1.53	1.40	1.64
T.S. 11 Emulsion Treated Base	5	1.60	1.27	1.27	1.44	2.00	1.89	1.68	1.65	1.34	1.61
T.S. 12 Petromat	2	1.95	1.74	1.56	1.47	2.28	2.45	2.39	2.05	1.43	1.86
T.S. 13 Fiberglass	2	1.76	1.36	1.30	1.20	2.21	2.20	1.89	1.92	1.32	1.65
T.S. 14 Petroset Flush	4	1.93	1.74	1.65	1.89	2.30	2.85	2.36	2.15	1.86	2.00
T.S. 15 Petroset in Cracks	4	1.89	1.60	1.28	1.47	2.39	2.37	2.07	2.05	1.70	1.87
T.S. 16 Reclamite in Cracks	4	1.40	1.05	1.04	1.19	2.03	2.27	1.91	1.98	1.44	1.50
T.S. 17 Reclamite Flush	3	1.24	1.10	1.06	1.12	1.47	2.00	1.31	1.32	.96	1.09
T.S. 18A Scarification & Reclamite 1¼" AC	12	.98	--	1.01	.79	.91	1.07	.99	.99	.81	1.16
T.S. 18B Scarification & Reclamite 3" AC	39	1.46	--	--	.99	1.12	1.21	1.37	1.45	.94	1.61
T.S. 18C Scarification & Reclamite 1½" AC	37	.83	--	--	.87	.94	1.28	1.35	1.31	.92	1.44
EB Control 1¼" AC	20	1.51	--	.62	1.22	2.04	1.88	1.87	1.91	1.47	1.76

TABLE 8A

ABSOLUTE VISCOSITY IN POISES, TEST PERFORMED AT 140°F

Asphalt Grades	Before Overlay May, 1972	Sept. 1972	Years After Overlay 1973	1974	1975	1976	1977
40/50 Pen L.A. T.S. 8	2,492	6,622	37,732	44,782	38,269	36,615	42,511
60/70 Pen L.A. T.S. 5	1,252	4,427	---	---	36,101	---	---
85/100 Pen L.A. T.S. 6	1,018	5,443	8,422	14,272	35,510	32,116	27,618
120/150 Pen L.A. T.S. 7	542	822	---	3,627	3,962	5,326	7,520
120/150 Pen 4 C T.S. 9	669	1,431	3,416	3,836	4,351	7,500	5,280
200/300 Pen L.A. T.S. 10	258	1,006	1,410	1,423	2,329	4,665	6,070
Asphalt Rubber							
Seal Coat no ACFC T.S. 1	542*	---	---	1,221	2,041	1,070	1,350
Seal Coat with ACFC T.S. 3 & 4	542*	---	---	1,072	1,923	3,319	3,115
Heater Scarification	After Heating	After Flush					
with Petroset T.S. 2	251,584	2,787	4,622	8,116	36,253	28,951	36,311
with Reclamite T.S. 18	251,584	1,678	4,736	35,230	37,160	---	---
Other							
Asbestos	1,252	---	---	3,888	3,763	3,753	4,560
Emulsion Treated Base T.S. 11	3,426	---	---	20,160	36,352	37,133	28,290
AC with no ACFC T.S. 6	1,018	---	---	34,223	36,426	26,122	---
AC with ACFC	1,018	4,071	---	33,162	36,213	28,951	---
ACFC	1,018	4,432	35,261	31,341	38,175	---	---
Old AC	---	---	---	---	---	---	---

*Sample taken before mixing with rubber.

TABLE 8A (Cont'd)
PENETRATION VALUES FOR VARIOUS ASPHALT OPERATIONS

Asphalt Grades	Before Overlay May, 1972	Sept. 1972	Years After Overlay 1973	1974	1975	1976	1977
40/50 Pen L.A. T.S. 8	48	34	14	11	12	16	11
60/70 Pen L.A. T.S. 5	71	38	--	--	20	--	--
85/100 Pen L.A. T.S. 6	103	36	30	23	21	19	15
120/150 Pen L.A. T.S. 7	144	115	--	43	39	11	27
120/150 Pen 4 C. T.S. 9	127	70	45	41	38	21	35
200/300 Pen L.A. T.S. 10	242	89	70	70	54	31	33
Asphalt Rubber							
Seal Coat No. ACFC T.S. 1	144*	--	--	92	61	99	92
Seal Coat with ACFC T.S. 3 & 4	144*	--	--	89	66	60	67
Heater Scarification	After Heating	After Flush					
with Petroset T.S. 2	14	105	38	30	19	16	16
with Reclamite T.S. 18	14		39	22	18	--	--
Other							
Asbestos T.S. 5	71	--	--	39	44	30	39
Emulsion Treated Base T.S. 11	48	--	--	25	22	5	13
AC with no ACFC T.S. 6	103	--	--	21	21	26	--
AC with ACFC	103	41	--	23	21	--	--
ACFC	103	38	22	23	20	--	--
Old AC	18	--	6	--	2	6	15

*Sample taken before mixing with rubber.

TABLE 8A (Cont'd)
MICRO VISCOSITY VALUES, VISCOSITIES MEASURED AT 77°F
DISPLAYED IN MEGA-POISES

Asphalt Grades	Before Laydown May 72	Sept. 72	Years After Overlay 1973	1974	1975	1976	1977
40/50 Pen L.A. T.S. 8	3.49	7.78	53.90	87.50	69.20	41.0	91.0
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	32.7	45.5
120/150 Pen L.A. T.S. 7	.43	.57	---	4.64	5.60	95.0	12.7
120/150 Pen 4 C.T.S. 9	.52	1.61	4.20	5.24	6.10	21.1	7.1
200/300 Pen L.A. T.S. 10	.13	.97	1.61	1.59	2.90	9.8	8.5
Asphalt Rubber							
Seal Coat No ACFC T.S. 1	.43*	---	---	.88	2.16	.78	.91
Seal Coat with ACFC T.S. 3&4	.43*	---	---	.97	1.10	3.10	2.60
Heater Scarification	After Heating	After Flush					
with Petroset T.S. 2	60.00	1.42	5.92	9.91	28.00	40.7	40.3
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	10.1	5.7
Emulsion Treated Base T.S. 11	3.70	---	---	14.60	19.70	486.0	59.9
AC with no ACFC	.88	---	---	22.70	21.40	13.6	---
AC with ACFC	.88	5.30	---	18.20	21.60	32.7	---
ACFC	.88	5.60	17.40	18.20	27.70	---	---
Old AC	35.90	---	275.0	---	3170.	79.0	44.3

*Sample taken before mixing with rubber.

TABLE 8A (Cont'd)
RAPID ROSTLER - PERCENT ASPHALTENES (A) FOR VARIOUS OPERATIONS

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

Asphalt Grades	Before Overlay May, 1972	Sept. 1972	Years After Overlay 1973	1974	1975	1976	1977
40/50 Pen L.A. T.S. 8	30.1	33.6	30.2	32.7	29.6	38.3	33.0
60/70 Pen L.A. T.S. 5	20.5	30.4	--	--	29.-	--	--
85/100 Pen L.A. T.S. 6	26.2	36.4	29.4	--	35.5	36.3	33.4
120/150 Pen L.A. T.S. 7	28.1	32.5	--	26.3	28.4	35.7	30.6
120/150 Pen 4 C. T.S. 9	13.5	15.5	15.4	15.0	16.1	24.8	20.5
200/300 Pen L.A. T.S. 10	20.0	26.4	26.4	26.9	27.3	33.2	29.8
Asphalt Rubber							
Seal Coat no ACFC T.S. 1	28.1	--	--	25.9	29.5	31.4	28.4
Seal Coat with ACFC T.S. 3 & 4	28.1	--	--	27.2	24.9	28.9	26.7
Heater Scarification	After Heating	After Flush	April 1972	1974	1975	1976	1977
with Petroset T.S. 2	43.4	32.4	23.1	30.0	33.5	33.4	35.0
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	27.4	24.5
Emulsion Treated Base T.S. 11	--	--	--	30.8	32.5	49.9	45.6
AC with no ACFC T.S. 6	26.2	--	29.4	35.3	35.5	31.4	--
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	48.7	45.2

*Sample Taken before mixing with rubber.

TABLE 9A
CORRELATION OF PSI - 18 KIP CUMULATIVE TRAFFIC

NUMBER OF OBSERVATIONS = 6

PSI = A-B (CUMULATIVE TRAFFIC IN EQUIVALENT 18 KIP)

	TEST SECTION	R^2	A	B
#1	Asphalt Rubber Flush-In	.81209	2.902	-1.57×10^{-6}
#2	Heater Scarification Plus Petroset	.91936	4.884	-2.275×10^{-6}
#3&4	Asphalt Rubber Under ACFC	.96328	4.280	-1.985×10^{-6}
#5	Asbestos	.96001	4.388	-1.334×10^{-6}
#6	2" AC No ACFC	.83951	4.205	-1.714×10^{-6}
#7	LA Basin 120/150 Penetration	.84033	4.429	-1.194×10^{-6}
#8	LA Basin 40/50 Penetration	.97033	4.653	-3.005×10^{-6}
#9	Four Corners 120/150 Penetration	.98507	4.909	-2.812×10^{-6}
#10	LA Basin 200/300 Penetration	.84788	4.758	-1.130×10^{-6}
#11	Emulsion Treated Base	.91025	3.872	-1.793×10^{-6}
#12	Petromat	.86034	4.783	-2.200×10^{-6}
#13	Fiberglass	.92076	4.594	-2.263×10^{-6}
#14	Petroset Flush-In	.98378	4.533	-2.826×10^{-6}
#15	Petroset Placed In Cracks	.98563	4.834	-2.749×10^{-6}
#16	Reclamite Placed in Cracks	.98584	4.770	-2.920×10^{-6}
#17	Reclamite Flush-In Heater Scarification Plus Reclamite	.99567	4.860	-2.546×10^{-6}
#18A&C	1-1/4" AC + .5" ACFC Overlay	.96452	4.714	-2.160×10^{-6}
#18B	3" AC + .5" ACFC Overlay	.80065	4.777	$- .834 \times 10^{-6}$

Appendix B

GUIDELINE FOR DETERMINATION OF PERCENT CRACKING

In the past, guidelines for determination of cracking have been cumbersome to use. In addition, once in use, output from crack surveys has been difficult to quantify for purposes of pavement evaluation and subsequent rehabilatation design. As such, a new system of analyzing cracking is recommended. This system is based on work done on the Minnetonka project.

The recommended procedure for determining percent cracking feet of cracking would be the following:

Locate a 50' x 20' section of roadway, preferably at a milepost. From the photos and drawings, match the percent cracking. For percentages less than 10, round to nearest 1 percent. For cracking greater than 10 percent, round to the nearest 5 percent.

PERCENT CRACKING

2.0

5.0

7.4

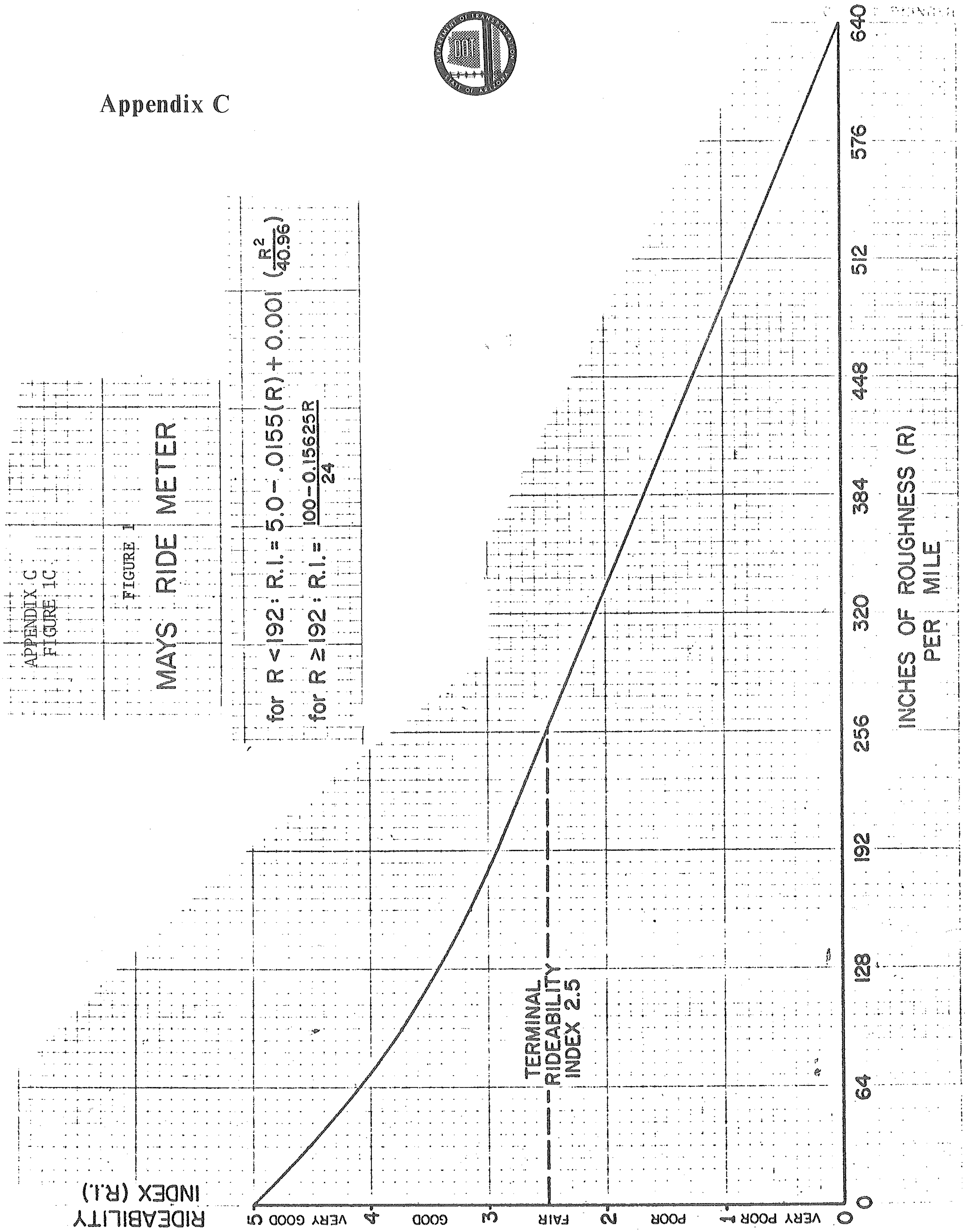
PERCENT CRACKING

11

35

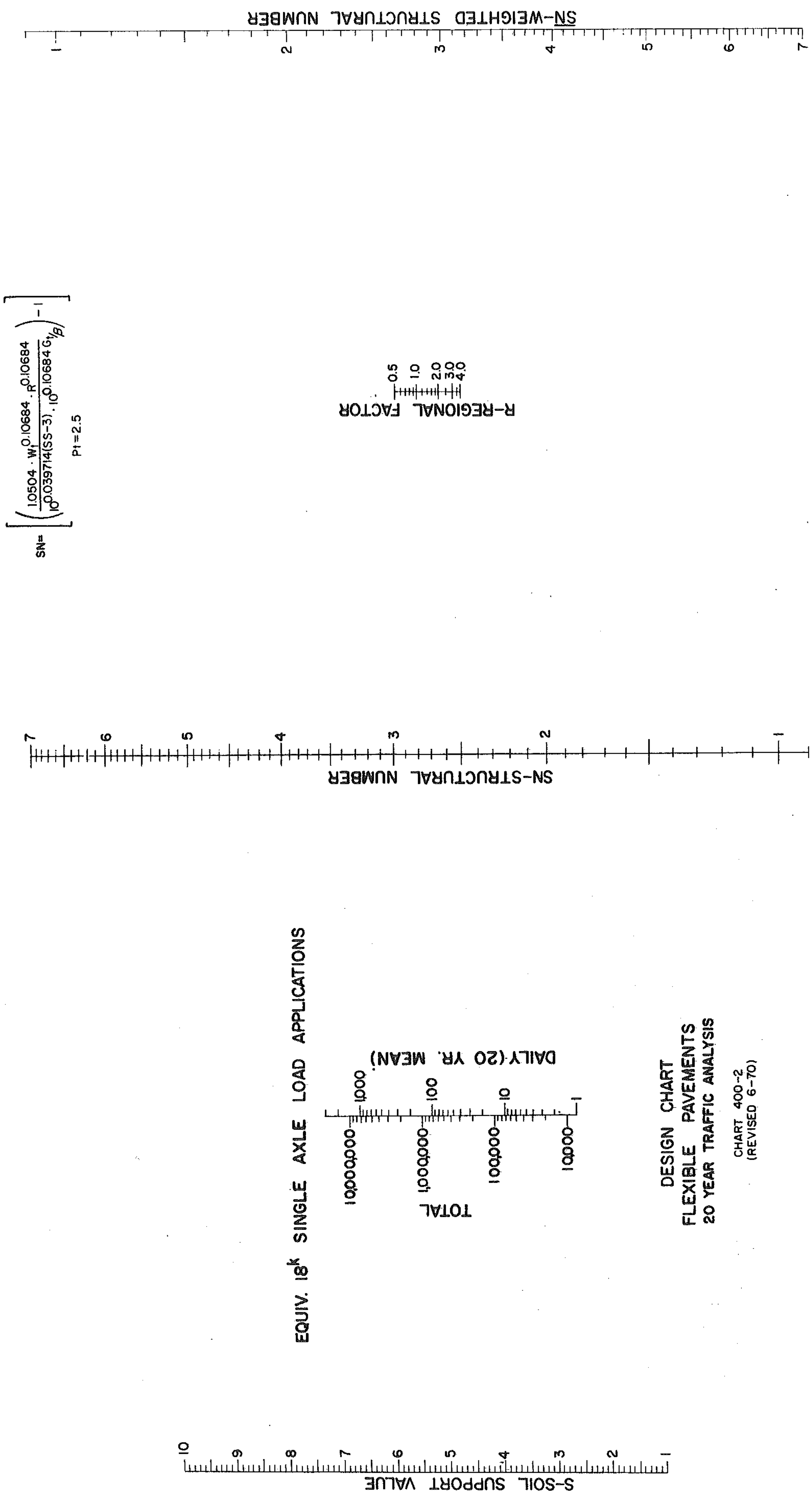
64

Appendix C



APPENDIX C
FIGURE 1C
FIGURE 1
MAYS RIDE METER
for R < 192 : R.I. = 5.0 − .0155(R) + 0.001 ($\frac{R^2}{40.96}$)
for R ≥ 192 : R.I. = $\frac{100 - 0.15625R}{24}$
RIDEABILITY INDEX (R.I.)
5 VERY GOOD
4
GOOD
3
FAIR
2
POOR
1 VERY POOR
0
TERMINAL RIDEABILITY INDEX 2.5
0
64
128
192
256
320
384
448
512
576
640
INCHES OF ROUGHNESS (R) PER MILE

FIGURE 2C


SN-WEIGHTED STRUCTURAL NUMBER
SN= [(1.0504 · W1^0.10684 · R^0.10684 / 10^0.039714(SS-3) · 10^0.10684 Gt/β) - 1]
Pt = 2.5
R-REGIONAL FACTOR
0.5 1.0 2.0 3.0 4.0
SN-STRUCTURAL NUMBER
EQUIV. 18k SINGLE AXLE LOAD APPLICATIONS
TOTAL
10,000,000 1,000,000 100,000 10,000
DAILY (20 YR. MEAN)
1000 100 10 1
DESIGN CHART
FLEXIBLE PAVEMENTS
20 YEAR TRAFFIC ANALYSIS
CHART 400-2
(REVISED 6-70)
S-SOIL SUPPORT VALUE