Structural Overlay Strategies for Jointed Concrete Pavements

Volume VI Appendix A - Users Manual for the EXPEAR Computer Program

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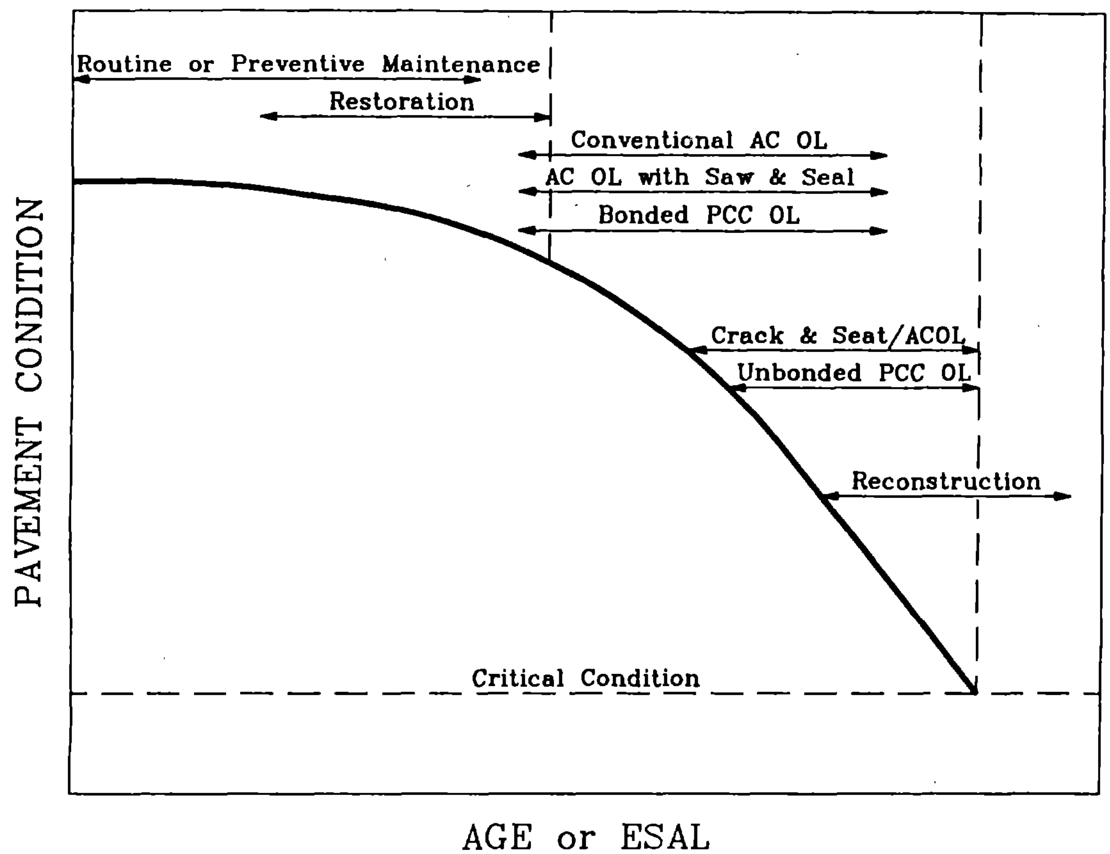

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Federal Highway Administration

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FOREWORD

This report is volume six of a six-volume set of reports with the title, STRUCTURAL OVERLAY STRATEGIES FOR JOINTED CONCRETE PAVEMENTS. The first five volumes have been distributed. Volume V, Summary of Research Findings, and the Technical Summary will be given widespread distribution. This volume will be distributed to those who request copies of the microcomputer program EXPEAR, an advisory system for selecting the most appropriate rehabilitation strategy for portland cement concrete pavements.

This report will be of interest to researchers and designers interested in the rehabilitation of portland cement concrete pavements.

The EXPEAR microcomputer program and documentation is available through McTRANS, Center for Microcomputers in Transportation, 512 Weil Hall, Gainesville, Florida 32611-2083 or PC-TRANS, University of Kansas Transportation Center, 2011 Learned Hall, Lawrence, Kansas 66045. Copies of this report only are also available from the National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161. A small charge will be imposed for each copy ordered from NTIS.

Thomas J. Pasko, Jr., P.E.
Director, Office of Engineering and Highway Operations Research and Development

NOTICE

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16. Abstract

A major field study and evaluation has been conducted into the effectiveness of three structural overlay types for portland cement concrete (PCC) pavements. These include sawing and sealing asphalt concrete (AC) overlays of PCC pavements, cracking and seating PCC pavements prior to AC overlay, and constructing a thin bonded PCC overlay on top of the existing PCC pavement. Condition surveys, deflection testing, and roughness measurements were performed on a total of 55 sections. The performance of these sections was evaluated and the effectiveness of each overlay type analyzed. Based on the field data, guidelines were developed for the use of structural overlays.

This volume provides a users guide to the EXPEAR computerized system to assist practicing engineers in evaluating concrete highway pavements, in developing feasible rehabilitation alternatives, and in predicting the performance and cost-effectiveness of the alternatives. EXPEAR is intended for use by State highway engineers in project-level rehabilitation planning and design for conventional concrete pavements (JRCP, JPCP, and CRCP). EXPEAR uses information about the pavement to guide the engineer through evaluation of a pavement's present condition and development of one or more feasible rehabilitation strategies. A computer program has been developed for each of the three pavement types addressed. The EXPEAR version 1.4 program operates on any IBM-compatible personal computer. Extensive revisions were made in EXPEAR 1.4 to improve the user-friendliness of the program and its capabilities.

This volume is the sixth in a series. The other volumes are:

FHWA No.	Vol. No.	Short Title
FHWA-RD-89-142	I	Sawing and Sealing of Joints in AC Overlays of Concrete Pavements
FHWA-RD-89-143	II	Cracking and Seating of Concrete Slabs Prior to AC Overlay
FHWA-RD-89-144	III	Performance Evaluation and Analysis of Thin Bonded Concrete Overlays
FHWA-RD-89-145	IV	Guidelines for the Selection of Rehabilitation Alternatives
FHWA-RD-89-146	V	Summary of Research Findings

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

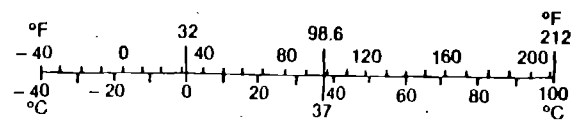
Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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1. INTRODUCTION

EXPEAR (EXpert system for Pavement Evaluation And Rehabilitation) is a practical and comprehensive computerized system to assist practicing engineers in evaluating concrete highway pavements, developing feasible rehabilitation alternatives, and predicting the performance and cost effectiveness of the alternatives. EXPEAR was originally developed for the Federal Highway Administration (FHWA) by the University of Illinois in 1985-1987.[1] It has been further developed with the support of the Illinois Department of Transportation (1988-1989). Additional work on EXPEAR has been supported by the FHWA under this research study.[2]

EXPEAR is intended for use by State highway engineers in project-level rehabilitation planning and design for high-volume (i.e., Interstate) conventional concrete pavements (jointed reinforced concrete pavement [JRCP], jointed plain concrete pavement [JPCP], and continuously reinforced concrete pavement [CRCP]). EXPEAR does not perform thickness or joint design; the engineer must use existing design procedures to determine these details.

EXPEAR has been developed in the form of a knowledge-based expert system, which simulates a consultation between an engineer and an expert in concrete pavements. EXPEAR uses information about the pavement to guide the engineer through evaluation of a pavement's present condition and development of one or more feasible rehabilitation strategies. The procedure was developed through extensive interviewing of authorities on concrete pavement performance. In addition, predictive models are included to show future pavement performance with and without rehabilitation.

Evaluation of a pavement and development of feasible rehabilitation alternatives is performed according to the following steps:

1. Project data collection.
2. Extrapolation of overall project condition.
3. Evaluation of present condition.
4. Prediction of future condition without rehabilitation.
5. Recommendations for physical testing.
6. Selection of main rehabilitation approach.
7. Development of detailed rehabilitation strategy.
8. Prediction of rehabilitation strategy performance.
9. Cost analysis of rehabilitation alternative.
10. Selection of preferred rehabilitation strategy.

A computer program has been developed for each of the three pavement types addressed. The programs operate on any IBM-compatible personal computer. The current version is EXPEAR 1.4, which possesses the capabilities to do life-cycle cost analysis and delay rehabilitation up to 5 years. Many revisions were made in EXPEAR 1.4 to improve the user friendliness of the program.

2. PAVEMENT EVALUATION

Step 1. Data Collection and Entry

The engineer collects inventory and monitoring data for the project. Inventory data, which should be available from office records, includes design traffic, materials, soils, and climate. Monitoring data includes distress, drainage characteristics, rideability, and other items collected during a field visit to the project. Monitoring data is collected by sample unit; a sufficient number of sample units distributed throughout the project's length should be surveyed to obtain a reasonable representation of the project's condition.

It is recommended that a team of two engineers perform the project survey together. They should drive over the entire length of the project and rate the present serviceability in each lane. They should also note the number and location of settlements and heaves. They should then return to the start of the project and perform the distress survey by sample unit. It is convenient to start sample units at mileposts for easy reference.

Either the pavement distress identification manual provided in NCHRP Report No. 277 or the Strategic Highway Research Program (SHRP) Long-Term Pavement Performance (LTPP) distress identification manual should be used as a guide.[3,4] These manuals provide standard definitions for distresses by type, severity, and unit of measurement. They also provide photographs of distresses to assist the engineers in rating their severity. The engineers must also measure faulting at joints, cracks, and full-depth repair joints.

In the office, the data are entered into a personal computer using a full-screen editor. The format of the data entry screens is very similar to that of the field survey sheets. The editor provides function keys for moving forward and backward through the data items and screens. The editor will provide screens for the project inventory data and monitoring data (1 set for each sample unit, up to a maximum of 10).

Step 2. Extrapolation of Overall Project Condition

Using the project length and lengths of the sample units, EXPEAR extrapolates from the sample unit distress data to compute the overall average condition of the project. The project is then evaluated on the basis of this average condition.

Step 3. Evaluation of Present Condition

EXPEAR utilizes a set of decision trees to analyze all of the data and develop a specific detailed evaluation in the following major problem areas for JRCP and JPCP:

- Roughness.
- Structural adequacy.
- Drainage.
- Joint deterioration.
- Foundation movement.
- Skid resistance.
- Joint construction.
- Loss of support.
- Load transfer.
- Joint sealant condition.
- Concrete durability.
- Shoulders.

The same problem areas are examined for CRCP, with the exception of those related to transverse joints (construction, deterioration, load transfer, and loss of support), and with the addition of a decision tree for construction joints and terminal treatments.

From the decision trees, a set of evaluation conclusions is produced for each traffic lane and each shoulder.

Step 4. Prediction of Future Condition Without Rehabilitation

Based on the current traffic level, in terms of the annual 18-kip (80 kN) Equivalent Single-Axle Load (ESAL) applications, and the anticipated ESAL growth rate, the future condition of the pavement without rehabilitation is predicted. Faulting, cracking, joint deterioration, pumping, and present serviceability rating are projected for jointed pavements (and punchouts for CRCP) and the years in which they will become serious problems are identified. The predictive models used are calibrated to the existing condition of the pavement at the time of the survey.

Step 5. Physical Testing Recommendations

The initial data collection does not require physical testing. Based upon the available information, the program identifies types of physical testing suggested to verify the evaluation recommendations and to provide data needed for rehabilitation design. Testing may include nondestructive deflection testing, coring/material sampling and laboratory testing, and roughness and friction measurement. Types of deficiencies which may warrant physical testing include structural inadequacy, poor rideability, poor surface friction, poor drainage conditions, poor concrete durability (D-cracking or reactive aggregate distress), foundation movement (due to swelling soil or frost heave), loss of load transfer at joints, loss of slab support, joint deterioration, and evidence of poor joint construction.

3. PAVEMENT REHABILITATION

Step 6. Selection of Main Rehabilitation Approach

Based upon the evaluation results, the system interacts with the engineer to select the most appropriate main rehabilitation approach for each traffic lane and shoulder. These include all 4R options: reconstruction (including recycling), resurfacing (with concrete or asphalt), or restoration. The major factors in determining whether a pavement needs reconstruction, resurfacing, or merely restoration are the extent of structural distress (e.g., cracking and corner breaks) and the extent of deterioration due to poor concrete durability (D-cracking or reactive aggregate distress).

Step 7. Development of Detailed Rehabilitation Strategy

Once an approach is selected for each traffic lane and shoulder, the engineer proceeds to develop the detailed rehabilitation alternative by selecting a feasible set of individual rehabilitation techniques to correct the deficiencies present. This may include such items as subdrainage, shoulder repair, full-depth repairs, joint resealing, etc. This is performed for each traffic lane and shoulder by interaction with the program. EXPEAR displays each of the evaluation conclusions reached earlier and recommends one or more appropriate rehabilitation techniques. A set of decision trees has been developed to guide the rehabilitation strategy development process for traffic lanes and for adjacent shoulders. Where more than one choice exists for an appropriate technique to repair a specific distress, the system presents the engineer with the choice to make.

EXPEAR computes needed quantities for the rehabilitation techniques selected based on the data in the project survey and additional information provided by the engineer. In general, the program assumes that 100 percent repair will be performed; that is, that the quantity of a certain type of distress to be repaired is equal to the quantity of that distress observed during the field survey.

If the rehabilitation work is being delayed, the quantities are increased where appropriate for each year of delay. Predictive models are used where available to increase the quantities. For distresses which do not have predictive models available, the quantities are increased by some constant amount (e.g., 5 percent per year).

When rehabilitation is delayed on a project which does not currently have any cracking or joint deterioration but which is predicted to develop some of either of these distresses between now and the time that the rehabilitation work will be done, appropriate quantities of full-depth repair are added to the rehabilitation strategy.

Step 8. Prediction of Rehabilitation Strategy Performance

The future performance of the developed rehabilitation strategy is predicted in terms of key distress types for 20 years into the future, based upon the traffic growth rate entered by the engineer. The JRCP and JPCP EXPEAR programs contain prediction models for the following key distresses for the various rehabilitation approaches:

• Reconstruction:	Faulting Cracking Pumping Joint deterioration PSR
• Bonded PCC overlay and Unbonded PCC overlay:	Faulting Cracking Joint deterioration
• AC structural overlay, AC nonstructural overlay, AC overlay/crack & seat, and AC overlay/saw & seal:	Reflective cracking Rutting
• Restoration:	Faulting: - with grinding - without grinding Full-depth repair faulting Cracking Pumping Joint deterioration PSR

The models are calibrated to the assumed condition of the pavement immediately after the rehabilitation is performed. If, for example, diamond grinding is not included in a restoration strategy, joint faulting after restoration is assumed to be the same value as was measured during the field survey, but if grinding is performed, joint faulting is assumed to be zero after the restoration.

EXPEAR evaluates the predicted performance of the rehabilitation strategy with respect to critical distress levels selected by the engineer, and determines in which years in the future these critical distress levels will be reached. From this information the predicted life of the rehabilitation strategy is determined as the earliest time when one of the distresses reaches a critical level (e.g., faulting exceeds 0.13 in [3.3 mm] for JPCP). The engineer may later override this life if desired.

Step 9. Cost Analysis of Rehabilitation Strategy

The first version of EXPEAR which was developed for the FHWA (EXPEAR 1.1) did not include the capability to perform a life-cycle cost analysis of the rehabilitation strategy developed. The most recent version of the program (EXPEAR 1.4) performs the cost analysis for the engineer. It uses the computed repair quantities and determines the rehabilitation alternative's life from the performance predictions. The engineer must specify the discount rate to be used in the analysis (values between 0 and 7 percent are permitted), and must also specify whether or not the rehabilitation will be delayed. Delays up to 5 years are permitted; considering the margin of error on some of the predictive models used by the program, it is not reasonable to assume the models can give meaningful predictions of the cost of rehabilitation postponed longer than that.

The engineer is given the opportunity to override the predicted life determined by the program. This may be desirable if the engineer has good reason to believe that the predicted life does not reflect the performance of that type of rehabilitation under the specific local conditions which apply to the pavement being considered. The cost analysis output indicates whether the life used in the computations was that predicted by the program or another value provided by the engineer.

EXPEAR also provides default unit costs for all of the rehabilitation techniques involved in the strategy being considered. The engineer may use these default costs or enter other values. Any number of sets of modified unit costs may be saved by the engineer and retrieved for future use.

EXPEAR computes the present cost and the equivalent annual cost of each technique over the entire project length, and summarizes the total present and annual costs of the strategy being examined. In the case of delayed rehabilitation, the program also computes the actual dollar cost of the rehabilitation in that year; that is, the "present cost" in the year the work is performed.

The cost analysis period is restricted to be the same as the first rehabilitation performance period. Therefore, it is not possible to include subsequent rehabilitation in the strategy to fill out a desired analysis period. This is largely due to the lack of predictive models for performance of such things as second overlays. It is also not possible to attach a salvage value to a strategy with a predicted life in excess of 20 years. When interpreting the results of the cost analyses for several strategies, the engineer must keep in mind that the analysis periods will in most cases be unequal. These limitations will be addressed in future improvements to EXPEAR.

The cost analysis in EXPEAR is a simple and approximate procedure, the primary purpose of which is to facilitate rapid generation and comparison of rehabilitation alternatives. It should help the engineer identify alternatives which are comparable in cost-effectiveness and deserve further investigation, and also eliminate alternatives which are clearly not cost-effective. It does not, however, take the place of the detailed evaluation and cost analysis which is required for preparation of plans, specifications, and bid estimates. It also does not consider cost items not directly related to improvement of the pavement (e.g., traffic control, bridge and guardrail work, etc.) though these costs may be incorporated into the engineer's unit costs if desired.

Step 10. Selection of Preferred Rehabilitation Strategy

EXPEAR can be used to develop several different rehabilitation strategies as described above. The costs and performance characteristics of each of these alternatives can be compared by the engineer. The one that fits the existing constraints and available funding the best can be identified.

4. EXPEAR OPERATION

System Requirements

Running EXPEAR requires an IBM DOS-compatible computer with approximately 350 Kbytes of free memory, and one of the following:

- Hard disk.
- Two 360 K, 5.25-in (133 mm) floppy disk drives.
- One 720 K, 3.5-in (89 mm) disk drive.

Hard disk operation is recommended both for speed of execution and storage of output files. EXPEAR will display on any type of monitor (monochrome, CGA, EGA, or VGA), and does not require a math coprocessor.

Each of the three EXPEAR versions (for the three pavement types: JPCP, JRCP, and CRCP) is distributed on a set of two 360 K, 5.25-in (133 mm) floppy disks. One disk contains the executable program (EXPEAR.EXE) and the second disk contains other files needed to run EXPEAR. The file names (EXPEAR.EXE, DISPLAYS.REC, STNDRD.DAT, etc.) are common to the programs for all three pavement types (JRCP, JPCP, and CRCP), so it is important that the programs for different pavement types be kept on separate floppy disks or separate hard disk directories.

Running EXPEAR

The program is started by typing "EXPEAR" from DOS. After the EXPEAR title screen and a few screens of introductory information, the system displays the main menu, which has four options:

MAIN MENU

1. ENTER OR EDIT PROJECT DATA
2. CONDUCT PROJECT EVALUATION
3. DEVELOP REHABILITATION STRATEGY
4. QUIT, RETURN TO DOS

Enter or Edit Project Data

When this option is selected, a menu will appear to ask whether you want to create a new data file or edit an existing file. A new data file is created by modifying the STNDRD.DAT file. If an existing data file is to be modified, the program will ask for the name of the data file without the .DAT extension.

A full-screen data editor is incorporated into the system for data entry and editing. Function keys for moving through the data items and screens are defined at the bottom of the screen. Some data items are defined as "toggle variables," meaning that available values (such as low, medium, high) can be selected using the tab key. After a file is edited, SHIFT-10 will exit the editor. This command does not however, save the file on disk. The program will prompt the user to save the file before continuing.

Conduct Project Evaluation

When this option is selected, the program asks for the name of the data file to be evaluated. It also asks whether the user wants to use the default critical distress levels incorporated in the program, or his or her own values. These may be selected each time the program is run, or may be saved to disk and retrieved when needed. The program will prompt the user for a file name under which to store critical distress values and save the file with a .CVL extension. Whether the default values or user-defined values are used, critical distress levels must be selected before proceeding with the evaluation.

The evaluation runs very quickly. When it is done, EXPEAR displays the results of the evaluation, which consists of evaluation conclusions for the traffic lanes and shoulders, predicted performance of each lane without rehabilitation, and physical testing recommendations. If the user desires, the data summary file and the project evaluation summary file may be printed from within the program. These files are saved on disk (with .REP and .TXT extensions) and may also be printed from DOS at a later time. However, if the user exits the program at this point and enters it again, the evaluation process must be repeated in order to proceed, because EXPEAR must have a current evaluation in memory in order to develop a rehabilitation strategy.

When the evaluation is completed, a menu appears with the following options:

EVALUATION MENU

1. DISPLAY EVALUATION CONCLUSIONS
2. DISPLAY PHYSICAL TESTING RECOMMENDATIONS
3. DISPLAY FUTURE DISTRESS AND PSR PREDICTIONS
4. PRINT EVALUATION SUMMARY
5. RETURN TO MAIN MENU

This permits the user to examine any part of the evaluation results, print the evaluation results, or bypass viewing the evaluation results and proceed directly to developing a rehabilitation strategy.

Develop Rehabilitation Strategy

When this option is selected, EXPEAR interacts with the user to select the main rehabilitation approach (reconstruct, overlay, or restore) and the specific rehabilitation techniques needed to correct the deficiencies identified in the evaluation. EXPEAR recommends appropriate rehabilitation approaches and techniques and gives the user the option to choose whenever more than one appropriate technique exists. EXPEAR does not have the capability to permit the user to enter options other than the ones given. When the list of techniques making up the rehabilitation strategy has been developed, it will be displayed along with approximate quantities. For some quantity calculations, additional user input is required for which a prompt appears on the screen. The rehabilitation techniques and quantities may be printed from EXPEAR or from DOS; the output file has an .DTS extension.

After a strategy has been developed, the rehabilitation menu appears with the following options:

REHABILITATION MENU

1. REVISE REHABILITATION STRATEGY
2. PREDICT REHABILITATION PERFORMANCE
3. PERFORM LIFE-CYCLE COST ANALYSIS
4. RETURN TO MAIN MENU

The second option will predict the performance of the rehabilitation strategy developed, using predictive models for key distresses. EXPEAR prompts the user for any additional information needed, such as overlay thickness. The predictions are displayed for each lane and may be printed from EXPEAR or from DOS (the output file's extension is .DRH).

Only after a rehabilitation strategy has been developed and its performance predicted can a cost analysis of the strategy be performed. EXPEAR prompts the user for a discount rate and the number of years that the rehabilitation will be delayed, and also asks the user to select unit cost values for the rehabilitation techniques. Default unit costs are provided, or (in the same manner as for critical distress levels), user-defined unit costs can be saved to disk (the file extension will be .UCC), and retrieved when needed.

The program computes the present and equivalent annual costs over the project length for the rehabilitation strategy analyzed. The annual cost is computed on the basis of the predicted life of the strategy, which is computed by EXPEAR but which may be overridden by the user if desired. The cost analysis results are displayed on the screen and may be printed from EXPEAR or from DOS (the extension is .LCC).

5. EXAMPLE PROBLEM

On the following pages, an example output from EXPEAR is provided for the case study of NC 1-8, a section of JPCP on Interstate 95 near Rocky Mount, North Carolina. The outputs include the following files:

- NC1-8.REP — Project Survey Summary
- NC1-8.TXT — Evaluation Results:
  - Extrapolated (Per Mile) Values
  - Evaluation Conclusions
  - Physical Testing Recommendations
  - Predicted Condition Without Rehabilitation
  - Future Pavement Evaluation
- NC1-8.DTS — Rehabilitation Techniques and Quantities for Restoration Alternative
- NC1-8.DRH — Predicted Performance for Restoration Alternative
- NC1-8.LCC — Life-cycle Cost Analysis for Restoration Alternative

The example output for this project is shown in tables 1 through 15.

Table 1. Project design data for NC 1-8.

PROJECT SURVEY SUMMARY FOR: NC 1-8

Design engineer: KTH Date of survey: 08/22/87

PROJECT IDENTIFICATION
Highway designation: I-95
State: North Carolina
Direction of survey: north
Starting milepost: 0.00
Ending milepost: 1.00

Number of sample units: 1

CLIMATE
Climatic zone: wet nonfreeze
Estimated annual temperature range (F): 60.0
Mean annual precipitation (inches): 46.8
Corps of Engineers freezing index (Fahrenheit degree-days): 0
Average annual temperature (degrees Fahrenheit): 60.0

SLAB CONSTRUCTION
Year constructed: 1967
Slab thickness (inches): 9.0
Width of traffic lanes (feet): 12.0
Concrete 28-day modulus of rupture (psi): 618

TRANSVERSE AND LONGITUDINAL JOINTS
Pattern of joint spacing: uniform
Average transverse joint spacing (feet): 30.00
Transverse joint sequence if random (feet):
Type of sealant: liquid
Average transverse joint reservoir dimensions:
width (inches): 0.50
depth (inches): 1.00
Method used to form transverse joints: sawing
Transverse joint sawed depth (inches): 1.00
Type of load transfer system: aggregate interlock
Dowel bar diameter (inches): 0.00
Method used to form longitudinal joints between lanes: sawing
Longitudinal joint sawed or formed depth (inches): 2.75

Table 1. Project design data for NC 1-8 (continued).

BASE
Base type: dense-graded untreated aggregate
Modulus of subgrade reaction (psi/inch): 513

SUBGRADE
Predominant subgrade soil AASHTO classification: A2
Are swelling soils a problem in area: no
Were steps taken to prevent the swelling soils problem: no

SHOULDER
Type of shoulder: AC
Width of shoulders (feet): inner: 6.0 outer: 10.2

Inner lane slope direction: toward inner shoulder

TRAFFIC
Estimated current through two-way ADT: 19100
Percent commercial trucks: 9.0
Total number of lanes in direction of survey: 2
Future 18-kip ESAL growth rate (percent per year): 4.0
Truck traffic volume growth rate: approximately same as in past

	Lane two	Lane one
Total accumulated 18-kip ESAL (millions):	1.88	9.14

RIDE QUALITY	Lane two	Lane one
PSR	3.7	3.3

1 in = 25.4 mm
1 ft = 0.3048 m
°F = 9/5(°C) + 32
1 psi = 0.00689 MPa

Table 2. Project survey summary for NC 1-8.

SAMPLE UNIT IDENTIFICATION

Sample unit number: 1 Starting milepost: 0.0

Length of sample unit (feet): 1068.0

	Lane two	Lane one
Number of deteriorated transverse cracks, L-M-H:	1	4
Mean faulting at transverse cracks (inches):	0.00	0.00
Number of deteriorated transverse joints:	1	1
Mean faulting at transverse joints (inches):	0.07	0.22
Number of transverse joints:	36	36
Number of FDRS & slab replacements:	0	0
Mean faulting at FDR & slab repl. jnts (inches):	0.00	0.00
Number of FDR & slab replacement joints:	0	0
Number of corner breaks:	0	0
Length of long. cracking, M-H only (feet):	0.0	0.0
Length of spalling of longit. joint, M-H only:	0.0	

CRACKING AT TRANSVERSE JOINTS

Total joints with trans. cracks within 2 feet:	0	0

FOUNDATION MOVEMENT

Number of settlements (M-H severity):	0	0
Number of heaves (M-H severity):	0	0

DRAINAGE

Are longitudinal subdrains present and functional: no

What is the typical height of the pavement above the ditchline: 6.0

Do ditches have standing water or cattails in them: no

LOSS OF SUPPORT

Extent of evidence of pumping or water bleeding:	none	none

SURFACE CONDITION

Method used to texture the pavement at construction: tine

Is the surface polished in the wheelpaths:	no	no
Is significant tire rutting in the wheelpaths:	no	no

JOINT SEALANT CONDITION

Condition of the transverse joint sealant:	low	low
Condition of the longitudinal joint sealant:	low	
Are substantial amnts of incompressibles in jnts:	no	no

Table 2. Project survey summary for NC 1-8 (continued).

CONCRETE DURABILITY		
Extent of "D" cracking at joints or cracks:	none	none
Extent of reactive aggregate distress:	none	none
Extent of scaling:	none	none
PREVIOUS REPAIR		
Are full-depth repairs placed with dowels:	n/a	n/a
Are partial depth repairs present at most joints:	no	no
Has diamond grinding been done:	no	no
Has grooving been done:	no	no
AC SHOULDERS	Inner	Outer
Alligator cracking:	none	none
Linear cracking:	none	none
Weathering/ravelling:	none	none
Lane/shoulder joint dropoff:	none	none
Settlements or heaves along outer edge:	none	none
Blowholes at transverse joints:	none	none
Lane/shoulder joint condition:	poor	poor

1 in = 25.4 mm
1 ft = 0.3048 m

Table 3. Extrapolated (per mile) values for NC 1-8.

Extrapolated (Per Mile) Values For NC 1-8

	Lane two	Lane one
Number of deteriorated transverse cracks:	5	20
Mean faulting at deter. trans. cracks (inches):	0.00	0.00
Number of deteriorated transverse joints:	5	5
Mean faulting at transverse joints (inches):	0.07	0.22
Number of transverse joints:	178	178
Number of full-depth repairs:	0	0
Mean faulting at FDR joints (inches):	0.00	0.00
Number of full-depth repair joints:	0	0
Number of corner breaks:	0	0
Length of long. cracking, M-H only (feet):	0.0	0.0
Length of spalling of longit. joint, M-H only:	0.0	
Total joints with trans. cracks within 2 feet:	0	0
Number of settlements (M-H severity):	0	0
Number of heaves (M-H severity):	0	0

1 in = 25.4 mm
1 ft = 0.3048 m
1 mi = 1.6 km

Table 4. Current pavement evaluation for lane 1 of NC 1-8.

CURRENT PAVEMENT EVALUATION

****
LANE 1
****

STRUCTURAL DEFICIENCY:
The pavement in lane 1 exhibits some load-associated distress (between 1 and 66 transverse cracks per mile) which requires repair but does not indicate a structural deficiency.

DRAINAGE DEFICIENCY:
The pavement in lane 1 shows no indications of a drainage deficiency.

FOUNDATION MOVEMENT:
The pavement in lane 1 shows no indications of foundation movement.

DURABILITY:
The pavement in lane 1 shows no indications of significant surface or concrete durability problems.

SKID RESISTANCE:
The pavement in lane 1 shows no indications of loss of skid resistance or hydroplaning potential.

ROUGHNESS:
Rideability in lane 1 is acceptable.

JOINT CONSTRUCTION:
The pavement in lane 1 shows no indications of a longitudinal joint construction deficiency.

The pavement in lane 1 shows no indications of a transverse joint construction deficiency.

Table 4. Current pavement evaluation for lane 1 of NC 1-8 (continued).

JOINT SEALANT:
Although the existing sealant in lane 1 is in good condition, a transverse joint sealant deficiency is indicated by an inadequate joint sealant reservoir width for the existing sealant type. This is likely to hinder the performance of the sealant in the future.

LOAD TRANSFER:
Aggregate interlock is providing inadequate load transfer in lane 1 at the transverse joints, as indicated by mean transverse joint faulting of more than 0.13 inches.

No load transfer deficiency is indicated at deteriorated transverse cracks in lane 1.

No undowelled full-depth repairs are present in lane 1.

LOSS OF SUPPORT:
The pavement in the lane 1 shows no indications of loss of slab support.

JOINT DETERIORATION:
Some joint deterioration exists (between 1 and 54 joints per mile) in lane 1, likely due to large joint movements associated with the long joint spacing.

1 in = 25.4 mm
1 mi = 1.6 km

Table 5. Current pavement evaluation for lane 2 of NC 1-8.

****

LANE 2

****

STRUCTURAL DEFICIENCY:
The pavement in lane 2 exhibits some load-associated distress (between 1 and 66 transverse cracks per mile) which requires repair but does not indicate a structural deficiency.

DRAINAGE DEFICIENCY:
The pavement in lane 2 shows no indications of a drainage deficiency.

FOUNDATION MOVEMENT:
The pavement in lane 2 shows no indications of foundation movement.

DURABILITY:
The pavement in lane 2 shows no indications of significant surface or concrete durability problems.

SKID RESISTANCE:
The pavement in lane 2 shows no indications of loss of skid resistance or hydroplaning potential.

ROUGHNESS:
Rideability in lane 2 is acceptable.

JOINT CONSTRUCTION:
The pavement in lane 2 shows no indications of a transverse joint construction deficiency.

Table 5. Current pavement evaluation for lane 2 of NC 1-8 (continued).

JOINT SEALANT:
Although the existing sealant in lane 2 is in good condition, a transverse joint sealant deficiency is indicated by an inadequate joint sealant reservoir width for the existing sealant type. This is likely to hinder the performance of the sealant in the future.

LOAD TRANSFER:
No load transfer deficiency is indicated at transverse joints in lane 2.

No undowelled full-depth repairs are present in lane 2.

LOSS OF SUPPORT:
The pavement in the lane 2 shows no indications of loss of slab support.

JOINT DETERIORATION:
Some joint deterioration exists (between 1 and 54 joints per mile) in lane 2, likely due to large joint movements associated with the long joint spacing.

1 in = 25.4 mm
1 mi = 1.6 km

Table 6. Current pavement evaluation for the shoulders of NC 1-8.

****
OUTER SHOULDER
****

Excessive infiltration of water beneath the pavement and outer AC shoulder is indicated by poor lane/shoulder joint sealant condition.

****
INNER SHOULDER
****

Excessive infiltration of water beneath the pavement and inner AC shoulder is indicated by poor lane/shoulder joint sealant condition.

Table 7. Physical testing recommendations for NC 1-8.

PHYSICAL TESTING RECOMMENDATIONS

-------------------- NONDESTRUCTIVE DEFLECTION TESTING --------------------

Nondestructive deflection testing (NDT) of the pavement is recommended to further investigate deficiencies observed in the preliminary evaluation of the pavement. Use a Falling Weight Deflectometer or other NDT device capable of applying dynamic loads to the pavement over a range of load levels comparable to actual truck wheel loads (i.e., 9000 to 16000 pounds).

Nondestructive deflection testing should be conducted in a 0.1-mile section randomly selected within each mile of the project. Deflection testing should only be conducted when the ambient temperature is between 50 and 80 degrees Fahrenheit to avoid joint and crack lock-up and excessive curling.

Testing should be performed at the following locations:

Center of the slab: Measure deflection basin in the center of the traffic lane in order to backcalculate elastic modulus of slab and effective k value beneath the slab. This information may be used in a structural analysis of the pavement and in determining uniformity of support along the project (see NCHRP Report No. 281).

Lane edge: Measure deflections at the outer edge of the traffic lane (next to the shoulder). If the pavement has a tied concrete shoulder, also measure deflections across lane/shoulder joint. This information may be used in a structural analysis of the pavement.

Corner of the slab: Measure deflections across transverse joints and cracks and compute their load transfer efficiencies. This information may be used in a structural analysis of the pavement.

Table 7. Physical testing recommendations for NC 1-8 (continued).

---------------------------- DESTRUCTIVE TESTING ----------------------------

Destructive testing (obtaining samples of material from the pavement structure) is recommended to further investigate deficiencies observed in the preliminary evaluation. Material samples must be obtained by coring through the concrete surface and base with a core bit (6-inch-diameter unless specified otherwise). Granular base bulk samples should be obtained. Stabilized base samples should be obtained from coring, if possible. Where undisturbed soil samples are required, they should be obtained by sampling the soil beneath the pavement and base a thin-walled Shelby tube.

Each type of destructive testing required should be conducted on at least one and preferably three or more slabs in each 0.1-mile section randomly selected within each mile of the project. For reasons of efficiency and safety, nondestructive testing and destructive testing should be conducted concurrently.

The following types of destructive testing are recommended:

Obtain cores from the center of the traffic lane.

Obtain cores through selected transverse joints.

Table 7. Physical testing recommendations for NC 1-8 (continued).

---------------------------- MATERIALS EVALUATION ----------------------------

Visual inspection and possibly laboratory testing of material samples obtained from destructive testing (coring) is recommended. The following types of information should be obtained from the material samples:

The strength of the cores obtained from the concrete slab should be determined by indirect tension testing in the laboratory. This information may be used in a structural analysis of the pavement. In the case of concrete deterioration due to poor durability (e.g., D cracking or reactive aggregate), the strength of the concrete is an indicator of the extent of the deterioration.

Examine the cores obtained from the center of the slab and through the transverse joints to determine the thickness and soundness of the concrete.

Determine the thickness of the base layer approximate depth measurements in the core hole.

-- SKID TESTING --

No skid testing of the pavement is warranted.

------------------------------------ ROUGHNESS TESTING ------------------------------------

Roughness testing is not warranted.

1 lb = 0.4536 kg
°F = 9/5(°C) + 32
1 in = 25.4 mm

Table 8. Future distress predictions without rehabilitation for lane 1 of NC 1-8.

FUTURE DISTRESS PREDICTIONS WITHOUT REHABILITATION

DISTRESS AND PSR PROJECTIONS FOR LANE 1

Cumulative ESAL	Annual ESAL	Year	Pumping	Faulting	Deter. Joints	Transverse Cracking	PSR
9.1	0.29	1987	0.0	0.22	5	20	3.3
9.4	0.30	1988	0.0	0.22	5	20	3.3
9.8	0.32	1989	0.0	0.22	5	20	3.2
10.1	0.33	1990	0.0	0.22	5	20	3.2
10.4	0.34	1991	0.1	0.22	5	21	3.1
10.8	0.36	1992	0.1	0.22	5	21	3.1
11.2	0.37	1993	0.1	0.22	5	21	3.1
11.5	0.38	1994	0.1	0.22	5	21	3.0
11.9	0.40	1995	0.1	0.22	5	21	3.0
12.4	0.42	1996	0.1	0.22	5	22	2.9
12.8	0.43	1997	0.1	0.22	5	22	2.9
13.2	0.45	1998	0.1	0.22	5	22	2.8
13.7	0.47	1999	0.2	0.22	5	22	2.8
14.2	0.49	2000	0.2	0.22	5	23	2.7
14.7	0.51	2001	0.2	0.22	5	23	2.7
15.2	0.53	2002	0.2	0.22	5	23	2.6
15.8	0.55	2003	0.2	0.22	5	23	2.5
16.3	0.57	2004	0.2	0.22	5	24	2.5
16.9	0.59	2005	0.3	0.22	5	24	2.4
17.6	0.62	2006	0.3	0.22	5	24	2.4
18-kip millions	18-kip millions		0 = none 1 = low 2 = medium 3 = high	Inches	Joints per mile	Cracks per mile	0-5

NOTE: These projections are estimates of expected performance based on predictive models. They should not be taken as exact values, but instead as relative indicators of performance.

1 in = 25.4 mm
1 mi = 1.6 km

Table 9. Future distress predictions without rehabilitation for lane 2 of NC 1-8.

FUTURE DISTRESS PREDICTIONS WITHOUT REHABILITATION

DISTRESS AND PSR PROJECTIONS FOR LANE 2

Cumulative ESAL	Annual ESAL	Year	Pumping	Faulting	Deter. Joints	Transverse Cracking	PSR
1.9	0.07	1987	0.0	0.07	5	5	3.7
2.0	0.07	1988	0.0	0.07	5	5	3.7
2.0	0.07	1989	0.0	0.07	5	5	3.7
2.1	0.08	1990	0.0	0.07	5	5	3.7
2.2	0.08	1991	0.0	0.07	5	5	3.6
2.3	0.08	1992	0.0	0.07	5	5	3.6
2.4	0.09	1993	0.0	0.07	5	6	3.6
2.4	0.09	1994	0.1	0.07	5	6	3.6
2.5	0.09	1995	0.1	0.07	5	6	3.6
2.6	0.10	1996	0.1	0.07	5	6	3.6
2.7	0.10	1997	0.1	0.07	5	6	3.5
2.8	0.11	1998	0.1	0.08	5	6	3.5
3.0	0.11	1999	0.1	0.08	5	6	3.5
3.1	0.11	2000	0.1	0.08	5	6	3.5
3.2	0.12	2001	0.1	0.08	5	6	3.5
3.3	0.12	2002	0.1	0.08	5	7	3.4
3.4	0.13	2003	0.1	0.08	5	7	3.4
3.6	0.13	2004	0.1	0.08	5	7	3.4
3.7	0.14	2005	0.1	0.08	5	7	3.4
3.9	0.14	2006	0.2	0.08	5	7	3.3
18-kip millions	18-kip millions		0 = none 1 = low 2 = medium 3 = high	Inches	Joints per mile	Cracks per mile	0-5

NOTE: These projections are estimates of expected performance based on predictive models. They should not be taken as exact values, but instead as relative indicators of performance.

1 in = 25.4 mm
1 mi = 1.6 km

Table 10. Future pavement evaluation for lane 1 of NC 1-8.

FUTURE PAVEMENT EVALUATION

****
LANE 1
****

ROUGHNESS:

Poor rideability in lane 1 occurs in 1994 as indicated by an unacceptably low predicted PSR for the pavement's ADT level.

JOINT DETERIORATION:

No significant joint deterioration in lane 1 occurs over the next 20 years.

STRUCTURAL DEFICIENCY:

No structural deficiency in lane 1 occurs based on predicted transverse cracking over the next 20 years.

LOAD TRANSFER:

Inadequate load transfer at transverse joints in lane 1 occurs in 1987 as indicated by predicted faulting of 0.13 inches or more.

LOSS OF SUPPORT:

Loss of slab support in lane 1 occurs in 1987 as indicated by predicted faulting greater than 0.13 inches at transverse joints.

DRAINAGE DEFICIENCY:

No drainage deficiency in lane 1 occurs over the next 20 years, based on the predicted level of pumping.

Table 11. Future pavement evaluation for lane 2 of NC 1-8.

FUTURE PAVEMENT EVALUATION

****

LANE 2

****

ROUGHNESS:

Rideability in lane 2 is acceptable based on ADT and PSR levels predicted over the next 20 years.

JOINT DETERIORATION:

No significant joint deterioration in lane 2 occurs over the next 20 years.

STRUCTURAL DEFICIENCY:

No structural deficiency in lane 2 occurs based on predicted transverse cracking over the next 20 years.

LOAD TRANSFER:

No load transfer deficiency at transverse joints in lane 2 occurs based on predicted joint faulting over the next 20 years.

LOSS OF SUPPORT:

No loss of slab support in lane 2 occurs based on predicted joint faulting over the next 20 years.

DRAINAGE DEFICIENCY:

No drainage deficiency in lane 2 occurs over the next 20 years, based on the predicted level of pumping.

Table 12. Rehabilitation strategy for NC 1-8.

REHABILITATION STRATEGY FOR NC 1-8: RESTORE BOTH LANES

YEAR(S) REHABILITATION WILL BE DELAYED : 5

Rehabilitation Techniques for Lane 1 with Required Quantities:

Full-depth repair of cracks	:	166 sq yards
Full-depth repair of joints	:	40 sq yards
Reseal transverse joints	:	2053 feet
Grinding	:	7040 sq yards

Rehabilitation Techniques for Lane 2 with Required Quantities:

Full-depth repair of cracks	:	44 sq yards
Full-depth repair of joints	:	40 sq yards
Reseal transverse joints	:	2053 feet
Grinding	:	7040 sq yards

Rehabilitation Techniques for Outer Shoulder with Required Quantities:

Reseal lane/shoulder joint	:	5280 feet

Rehabilitation Techniques for Inner Shoulder with Required Quantities:

Reseal lane/shoulder joint	:	5280 feet

1 yd = 0.9144 m
1 ft = 0.3048 m
1 in = 25.4 mm

Table 13. Predicted performance following restoration for lane 1 of NC 1-8.

PREDICTED PERFORMANCE FOR LANE 1 FOLLOWING RESTORATION
YEAR(S) REHABILITATION WILL BE DELAYED : 5

Year	Age	Cum ESALs	Joint Faulting	FDR Faulting	Transverse Cracking	Joint Deter	Pumping	PSR
1992	25	9.44	0.00	0.00	0	0	0.0	4.5
1993	26	9.76	0.03	0.00	0	0	0.2	4.4
1994	27	10.09	0.04	0.00	0	0	0.3	4.4
1995	28	10.43	0.05	0.00	1	0	0.3	4.3
1996	29	10.79	0.06	0.00	1	0	0.4	4.3
1997	30	11.16	0.07	0.00	1	0	0.4	4.3
1998	31	11.54	0.07	0.00	1	0	0.4	4.3
1999	32	11.94	0.08	0.00	1	0	0.5	4.3
2000	33	12.36	0.09	0.00	2	0	0.5	4.2
2001	34	12.79	0.09	0.00	2	0	0.5	4.2
2002	35	13.24	0.10	0.00	2	0	0.6	4.2
2003	36	13.71	0.10	0.00	2	0	0.6	4.2
2004	37	14.19	0.11	0.00	3	0	0.6	4.2
2005	38	14.70	0.11	0.00	3	0	0.6	4.1
2006	39	15.23	0.12	0.00	3	0	0.7	4.1
2007	40	15.77	0.12	0.00	3	0	0.7	4.1
2008	41	16.34	0.13	0.00	4	0	0.7	4.1
2009	42	16.93	0.13	0.00	4	0	0.7	4.1
2010	43	17.55	0.14	0.00	4	0	0.8	4.1
2011	44	18.19	0.14	0.00	4	0	0.8	4.1
		18-kip millions	Inches	Inches per mile	Cracks per mile	Joints	0 = none 1 = low 2 = medium 3 = high	0-5

NOTE: These projections are estimates of expected performance based on predictive models. They should not be taken as exact values, but instead as relative indicators of performance.

SUMMARY:

Joint faulting on the restored pavement in lane 1 is predicted to equal or exceed an unacceptable level of 0.13 inches in 2008.

Cracking on the restored pavement in lane 1 is not predicted to reach an unacceptable level within the next twenty years.

Joint deterioration on the restored pavement in lane 1 is not predicted to reach an unacceptable level within the next twenty years.

PSR on the restored pavement in lane 1 is not predicted to reach an unacceptable level within the next twenty years.

1 in = 25.4 mm
1 mi = 1.6 km

Table 14. Predicted performance following restoration for lane 2 of NC 1-8.

PREDICTED PERFORMANCE FOR LANE 2 FOLLOWING RESTORATION
YEAR(S) REHABILITATION WILL BE DELAYED : 5

Year	Age	Cum ESALs	Joint Faulting	FDR Faulting	Transverse Cracking	Joint Deter	Pumping	PSR
1992	25	1.95	0.00	0.00	0	0	0.0	4.5
1993	26	2.03	0.02	0.00	0	0	0.1	4.4
1994	27	2.10	0.04	0.00	0	0	0.1	4.4
1995	28	2.18	0.05	0.00	0	0	0.2	4.4
1996	29	2.27	0.05	0.00	0	0	0.2	4.3
1997	30	2.35	0.06	0.00	1	0	0.2	4.3
1998	31	2.44	0.07	0.00	1	0	0.2	4.3
1999	32	2.54	0.07	0.00	1	0	0.2	4.3
2000	33	2.63	0.08	0.00	1	0	0.3	4.3
2001	34	2.74	0.08	0.00	1	0	0.3	4.3
2002	35	2.84	0.09	0.00	1	0	0.3	4.2
2003	36	2.95	0.09	0.00	1	0	0.3	4.2
2004	37	3.07	0.10	0.00	1	0	0.3	4.2
2005	38	3.18	0.10	0.00	1	0	0.3	4.2
2006	39	3.31	0.10	0.00	2	0	0.4	4.2
2007	40	3.44	0.11	0.00	2	0	0.4	4.2
2008	41	3.57	0.11	0.00	2	0	0.4	4.2
2009	42	3.71	0.12	0.00	2	0	0.4	4.1
2010	43	3.85	0.12	0.00	2	0	0.4	4.1
2011	44	4.00	0.12	0.00	2	0	0.4	4.1
		18-kip millions	Inches	Inches per mile	Cracks per mile	Joints	0 = none 1 = low 2 = medium 3 = high	0-5

NOTE: These projections are estimates of expected performance based on predictive models. They should not be taken as exact values, but instead as relative indicators of performance.

SUMMARY:

Joint faulting on the restored pavement in lane 2 is not predicted to reach an unacceptable level within the next twenty years.

Cracking on the restored pavement in lane 2 is not predicted to reach an unacceptable level within the next twenty years.

Joint deterioration on the restored pavement in lane 2 is not predicted to reach an unacceptable level within the next twenty years.

PSR on the restored pavement in lane 2 is not predicted to reach an unacceptable level within the next twenty years.

1 in = 25.4 mm
1 mi = 1.6 km

Table 15. Life-cycle cost analysis of rehabilitation strategy for NC 1-8.

LIFE-CYCLE COST ANALYSIS OF REHABILITATION STRATEGY

Project	:	NC1-8
Strategy	:	RESTORE BOTH LANES
Year to Perform Rehabilitation	:	1992
Year(s) Rehabilitation Delayed	:	5
Discount Rate	:	3.0 percent
Analysis Period	:	16 years (program prediction)

REPAIR TECHNIQUES	QUANTITIES NEEDED	UNIT COST	REHAB COST	ANNUAL COST
OUTER LANE				
Full-depth repair of cracks	166 sy	148.00	24573	1687
Full-depth repair of joints	40 sy	148.00	5853	402
Reseal transverse joints	2053 ft	1.75	3592	247
Grinding	7040 sy	3.50	24640	1692
INNER LANE				
Full-depth repair of cracks	44 sy	148.00	6449	443
Full-depth repair of joints	40 sy	148.00	5853	402
Reseal transverse joints	2053 ft	1.75	3592	247
Grinding	7040 sy	3.50	24640	1692
OUTER SHOULDER				
Reseal lane/shoulder joint	5280 ft	1.25	6600	453
INNER SHOULDER				
Reseal lane/shoulder joint	5280 ft	1.25	6600	453

TOTALS:

TOTAL PRESENT COST	TOTAL REHABILITATION COST	TOTAL ANNUAL COST
96951	112393	7718

1 yd = 0.9144 m
1 ft = 0.3048 m
1 in = 25.4 mm

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