Development of a Routine Pavement Maintenance Data Base System

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When a routine maintenance management system is developed, the creation of a meaningful data base should be considered. In this paper is presented the development of a microcomputer data base that can be used at different maintenance management levels of the Indiana Department of Highways. To determine what type of data to include in the data base, the relationship between roughness and level of routine maintenance expenditure was analyzed. Condition survey information, based on unit foremen's evaluation of highway deficiencies, may be included in the proposed data base. The condition survey information along with roughness measurements can be used in two ways. First, the Central Office can use the information in programming maintenance and rehabilitation activities. Second, the data can be used by subdistricts to set priorities for routine maintenance work on highway sections within their jurisdictions. Information on rehabilitation activities, such as resurfacing, was included in the data base to increase the level of coordination between the programming of major maintenance and routine maintenance activities. This coordination may result in substantial savings in pavement maintenance and rehabilitation. Some other supplementary information, such as average daily traffic, contract number, county, subdistricts, and pavement type, was included in the data base. A pilot implementation plan is proposed. Performance of the data system in pilot implementation should be evaluated to provide the feedback necessary to assess the value of the information included in the data base.

Routine maintenance of the Indiana state highway system consumes from 40 to 50 percent of total highway expenditure *(1, 2)*. However, as in many other states, the routine maintenance program in Indiana is not effectively coordinated with major activity programs. This lack of coordination is because the philosophy of the development of major activity programs is different from that of routine maintenance programs.

Major activity programs identify highway sections that are at or near a prescribed structural failure level and then allocate resources to upgrade these sections within the available funds. Routine maintenance programs, on the other hand, consider only the apparent condition of a highway element (pavement surface condition of a highway) and try to keep the serviceability as high as possible, regardless of the structural adequacy of the highway element.

Although the criteria for the development of major activity programs may differ from those of routine maintenance programs, both programs have a common goal of preserving the condition of the highway system. An effective coordination between the two programs may result in considerable savings. For instance, sometimes expensive routine maintenance activities, such as seal coating, get applied on sections that have been scheduled to receive resurfacing within a few months *(3, 4)*. Such a situation arises in the absence of coordination. An effective exchange of information between two programs is thus essential. Figure 1 is a schematic presentation that shows an example of how information on seven major activities can relate to routine maintenance activities. Table 1 is a list of pavement maintenance activities included in the roadway and shoulder group.

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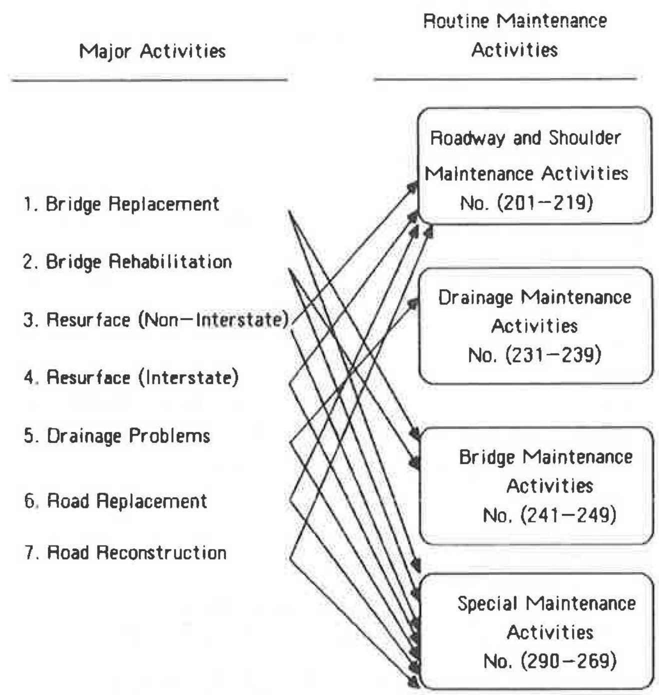

FIGURE 1 Relationship between major activities and routine maintenance activities.

TABLE 1 ROUTINE PAVEMENT MAINTENANCE ACTIVITIES

Activity	IDOH Code	Production Unit
Shallow patching	201	Tons of mix
Deep patching	202	Tons of mix
Premix leveling	203	Tons of premix
Seal coating	205	Lane-miles
Sealing longitudinal cracks and joints	206	Linear feet
Sealing cracks	207	Lane-miles
Cutting relief joints	209	Linear feet
Joint and bump burning	210	Bumps removed
Others	219	Man-hours

The purpose of this research effort was to develop a computerized information system that could transfer the available information on the current condition of highway elements and programmed improvement activities to different levels of routine maintenance management (central office, district, and subdistrict). It is believed that the availability of such information can result in substantial savings in maintenance expenditure and in the development of an effective maintenance program.

A routine maintenance data base system (RMDBS) is a procedure for collecting, storing, processing, and retrieving the information required in a maintenance management system. It represents the basis for a maintenance management system because all pavement decisions must be made according to a common, integrated source of information derived from reliable, good-quality data.

EFFECT OF ROUTINE MAINTENANCE ON PAVEMENT CONDITION

To ascertain what types of surface condition data were to be included in the information system, an analysis was performed to investigate the relationship between routine maintenance and surface roughness. For the purpose of this analysis, only the Interstate highway system was considered, and factors such as traffic level, surface type, and pavement age were taken into account. The general approach of the analysis can be summarized as follows:

1. Divide the network into homogeneous pavement sections,
2. Determine the roughness values and the years for the two most recent roughness measurements on each section,
3. Determine the amount of routine maintenance applied between two dates by type of maintenance activity on each section, and
4. Analyze the effect of routine maintenance expenditure level on the rate of change in roughness during the period between the two measurements.

The major findings of this analysis were as follows:

1. The rate of increase in roughness varied inversely with routine maintenance expenditure. This means that when a higher level of pavement maintenance expenditure is made on a section, it shows less increase in roughness (Figure 2).
2. Because maintenance records are available by highway sections within the boundaries of a county and roughness data are recorded by contract sections, the analysis was impaired because of inadequate location-specific data. Nevertheless, the analysis provided sufficient evidence that roughness measurements can be used as an indicator of routine maintenance needs. In other words, ranking of highway sections according to their roughness values can be used along with other information in making decisions about the allocation of highway routine maintenance funds.

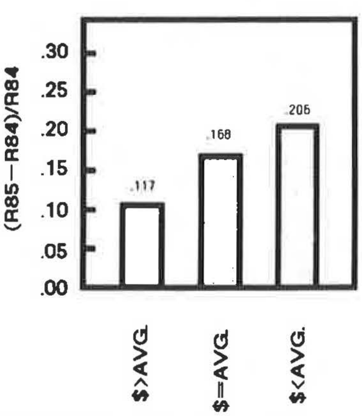

FIGURE 2 Effect of sealing expenditure (206 + 207) on level of roughness.

DEVELOPMENT OF A MICROCOMPUTER DATA BASE

When the proposed data base was developed, the following points were taken into consideration:

1. Use currently available data;
2. Structure the data base to permit future modifications and improvements;
3. Provide a data base that can provide management with timely access to the routine maintenance and capital programs information base at a reasonable cost; and
4. Simplify the use, maintenance, and updating of the data base.

Work Plan

The general approach followed to develop the data base can be summarized as follows:

1. Review of the existing maintenance computer files.
2. Transformation of the available highway information sources, such as highway inventory and roughness and skid resistance files, to a form suitable for use in the current organizational structure. For example, routine maintenance data are currently recorded by highway section in Indiana. A highway section refers to the stretch of a highway within the boundaries of a county. However, to be compatible with the other information, the records had to be reorganized so that they represented subdistrict boundaries.
3. Development of a computer file for future highway improvement programs.
4. Development of a computer program to prepare several information reports. These reports would inform various management units of actions taken by other units. For example, subdistricts would be able to identify sections with high roughness values and sections that were scheduled for future improvement activities in a specific location.

Data Base Elements

With the growth of available data and the increasing power of modern computers, managers are practically flooded with information. The problem is to discriminate among all of the data available and the data that the manager needs and can use. In the proposed integrated data base, only the data that can assist managers in identifying maintenance needs are included. The data base would be composed of the following three elements:

1. The Indiana Department of Highways (IDOH) roughness computer files,
2. Future programmed major activities, and
3. Results of condition survey.

These data base elements are shown in Figure 3.

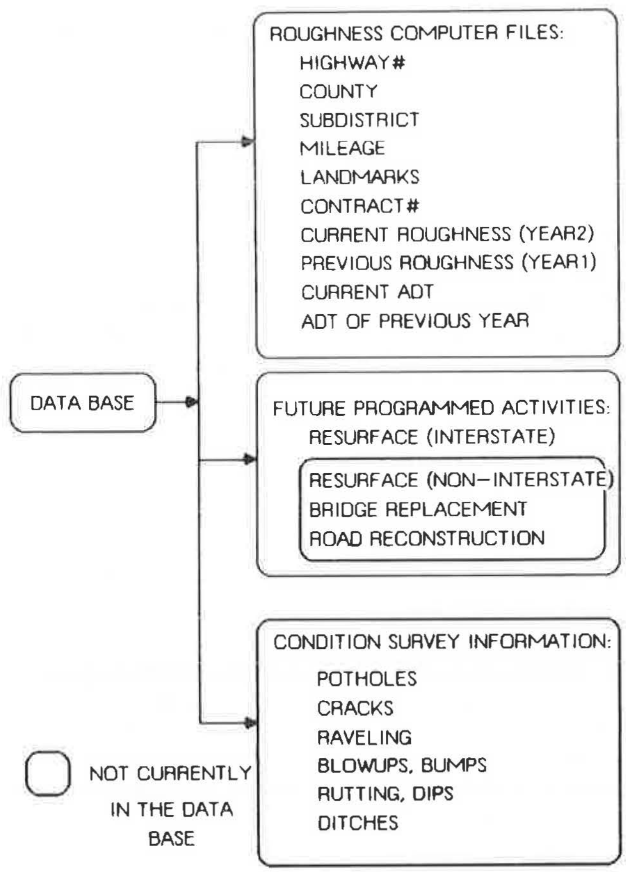

FIGURE 3 Data base elements.

IDOH Roughness Computer Files

The IDOH roughness computer files form the backbone of the proposed data base. The following information was taken from these computer files: highway number, county, year resurfaced, mileage, landmarks, contract number, current roughness, roughness of previous year, current average daily traffic (ADT), and the ADT of the previous year.

Future Programmed Major Activities

The future programmed major activities were taken from the Biennial Highway Improvement Program (HIP) *(5)*. In the HIP, projects are arranged in the following categories: bridges, resurfacing, safety improvements, roadside improvements, new facilities, park facilities, and toll facilities. Information from the 1984–1986 Biennial Highway Improvement Program was used in the data base developed in this study.

Condition Survey Information

The current pavement data collection program in Indiana does not include any kind of statewide condition surveys. Montenegro and Sinha *(6)* have recently proposed a periodic condition survey procedure to be carried out by unit foremen. The foremen would be responsible for filling out standard forms evaluating the condition of road sections within their respective units. If the survey procedure is implemented, this information would be entered into the computer and would be part of the proposed data base developed in the present study.

Uses of the Data Base

The possible uses of the proposed data base are

1. To provide timely information to managers in an understandable and easily applicable form;
2. To provide coordination between major maintenance and routine maintenance programs;
3. To provide uniform method for using surface condition data;
4. To provide information for the central office and district to use in setting priorities in the allocation of funds by activity and by subdistricts; this may be accomplished by using the results of the proposed condition survey, which may be included in the proposed data base; and
5. To allow subdistrict foremen to identify routine maintenance needs, set priorities on these needs, and program the work in accordance with the resulting priorities.

EXAMPLE APPLICATION OF THE DATA BASE SYSTEM

Personal computers are now in common use and have proven highly cost effective in information system applications. Therefore, the IBM personal computer was chosen to accommodate the proposed RMDBS for Indiana. The data base system includes a series of programs that interact with the users and produce simple reports about any specific highway section. For the purpose of this study, only the Interstate system was considered; the rest of the state highway system can be added later. The programming language of KnowledgeMan software *(7)* was used to write all of the computer programs.

Structure of the Data File

Because of the large size of the data file and the slow speed of the personal computer, the indexed sequential technique was used to access information quickly. The index file developed was named INDEX. This file is composed of 37 numbers, each of which is assigned to one of the 37 subdistricts in Indiana. Then the large data file was divided into 37 subfiles, so that each subfile includes the records of one subdistrict. A record can be defined as the set of information that describes a specific segment of the road within a subdistrict. When the computer program needs to access a specific record in a subdistrict, a search is made in the index file for the subdistrict, then a search for the record will be made only inside the subfile that includes the records for this specific subdistrict, as shown in Figure 4. This technique saves a great deal of computer time during the execution of the RMDBS, and it can help managers to obtain reports easily and quickly from the data base.

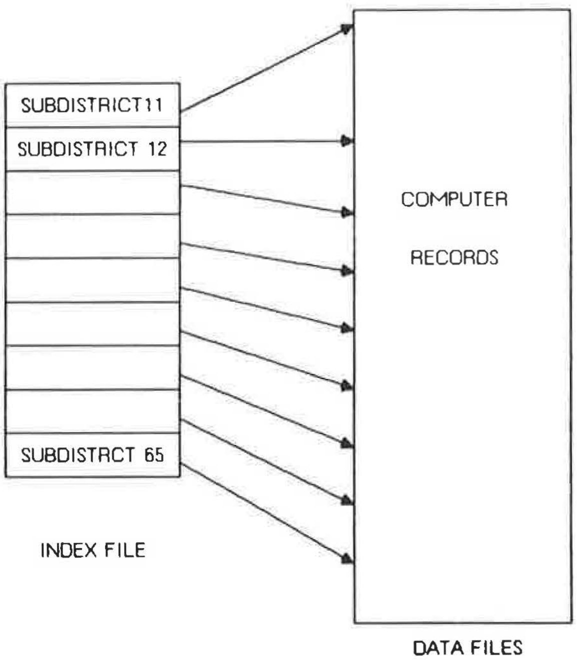

FIGURE 4 Hierarchical sequence structure.

Input Format

Communication between user and computer is perhaps the most difficult aspect of an information system. Therefore, the RMDBS was created as a tool that can be learned quickly by users of any level of computer background. The inputs and outputs of the program were made simple. Friendly interactive programs were developed to produce different menus that show the user the different available options from which he may choose. When the user selects an option, the program will automatically show a submenu, ask for information, or produce an informational report that matches the selected option. There are eight different menus; Figure 5 shows the main menu.

The program is set up so the user sees what input is typed, then the program checks the input and gives an error message if there is any input error. This kind of input is simple even for an inexperienced program user.

A carriage return locks the input to the indicated item and automatically advances to the next item for input. The item that is ready to receive an input is identified by underlining.

INDIANA DEPARTMENT OF HIGHWAYS
ROUTINE MAINTENANCE
DATA BASE SYSTEM
MAIN MENU

1. ADD HIGHWAY SECTIONS
2. MODIFY EXISTING INFORMATION
3. REPORT AND REVIEW INFORMATION
4. QUIT

SELECT A NUMBER:

FIGURE 5 RMDBS main menu.

Description of Output

The RMDBS produces 10 different reports:

1. Roughness report: This report gives the roughness measurements for the current and previous year. The roughness measurements are given between mileposts.
2. Increase in roughness report: This report shows the rate of increase in roughness between the current and the previous year for the specified section.
3. Mileage report: This report gives the milepost reading of the start and the end of the specified section.
4. Contract number report: This report shows the contract number of the specified section.
5. Date report: This report gives the date when the section was opened to traffic.
6. Traffic report: This report shows the ADT for the current and previous years.
7. Landmarks report: The landmarks that are within the boundaries of the section are shown in this report.
8. Surface type report: This report indicates whether the specified section is rigid or flexible.
9. Resurfacing project report: This report indicates anticipated future resurfacing projects and the cost of these projects.
10. Highway section report: This report lists all of the highway sections within a subdistrict.

More reports could be generated after condition survey information is added to the data base. These reports would indicate the type and extent of distress on each segment of the highway system.

If the user wants to get one of the reports, the roughness report for example, he has to operate the program to get the main menu (Figure 5). The menu consists of four options, and Option 3 will provide information and reports. After this procedure has been completed, the computer will present the user with the list of the subdistricts, and the user will choose the relevant subdistrict. The computer will then show all of the highway sections within this subdistrict and once again the user will select the appropriate section. Next, the user will select Option 1 from the menu shown in Figure 6 to get the available reports on roughness. The final step will be to choose Option 1 in the roughness and traffic information menu shown in Figure 7. Figure 8 shows the roughness report for a section in Terre Haute (Subdistrict 11).

INDIANA DEPARTMENT OF HIGHWAYS
ROUTINE MAINTENANCE DATABASE

1. ROUGHNESS & TRAFFIC INFORMATION
2. GENERAL INFORMATION
3. CONDITION SURVEY INFORMATION
4. BACK TO THE PREVIOUS MENU
5. QUIT

SELECT AN OPTION:

FIGURE 6 RMDBS information menu.

Software

Software is defined as computer programs, procedures, and associated documentation used in the operation of computer hardware. The two major categories of software are system programs and application programs.

System Programs

System programs are the computer programs used to coordinate and control the overall operation of a computer system. The PC-DOS 2.1 and KnowledgeMan 1.07 were the system programs used in the RMDBS.

Application Programs

Application programs are written for specific applications. These programs depend on the system programs during execution.

The RMDBS consists of 36 application programs. The operation of the RMDBS program is dependent on all of the available options, and all of the programs are therefore interrelated. Figure 9 shows the relationship among application programs, KnowledgeMan, and computer files.

INDIANA DEPARTMENT OF HIGHWAYS

ROUTINE MAINTENANCE DATABASE

1. ROUGHNESS FOR CURRENT AND PREVIOUS YEAR
2. ADT FOR CURRENT AND PREVIOUS YEAR
3. ROUGHNESS RATIO
4. BACK TO THE PREVIOUS MENU
5. QUIT

SELECT AN OPTION:

FIGURE 7 RMDBS roughness and traffic menu.

H.W. :70 Direction :E

Subdistrict :11 County :84

Mileage		Year 1	Year 2
From	To	Roughness	Roughness
0	1	378	423
1	2	431	497
2	3	376	336
3	4	425	337
4	5	490	416
5	6	385	694
6	7	417	970
7	8	406	1168
8	9	382	989
9	10	344	437
10	11	413	443
11	12	416	804
12	13	1906	399
13	14	1668	311

FIGURE 8 Example of roughness report produced by RMDBS.

The RMDBS programs serve four different purposes. They

1. Show different menus with available options,
2. Show the input menu to identify a section or to input condition survey data,
3. Produce reports according to the option selected by the user, and
4. Confirm input information and detect input errors.

Error Messages

Because of the simplicity of the input format, the user of the RMDBS can commit few input errors. The program prints error messages in response to the kind of errors detected. After

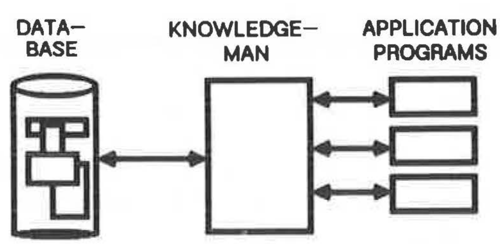

FIGURE 9 Relationship among application programs, KnowledgeMan, and the data base.

printing the error message, the program will give the user the opportunity to change the input.

System Configuration

The following computer components are essential to use of the RMDBS:

1. System unit, containing a minimum of IBM personal computer family with hard disk or true compatibles, monochromatic or color video monitor (25 lines × 80 characters), keyboard, and printer (80 column);
2. PC-DOS 2.1 or later version; and
3. KnowledgeMan software 1.07 or later version.

Information Updating

When the RMDBS was created, the need for continued updating of the data base was taken into consideration. The data of each record were divided into two parts:

1. The first part includes the results of the condition survey. It is proposed that these data be collected by the foremen. It is suggested that this part of the data base should be updated by subdistrict management. Then the information can be transferred to other management levels by computer instead of the condition survey forms. The updating of this part of the data base should be done twice each year because it is proposed that condition survey data be collected biannually.
2. The second part includes roughness, ADT, future programmed activities, and surface type. This part of the data should be updated by the central computing facilities in Indianapolis because all of these data are located in computer files there. The updating of this part should be done yearly because roughness measurements are collected on a yearly basis.

IMPLEMENTATION AND EVALUATION OF THE RMDBS

The following steps may be involved in implementation of the proposed information system on a pilot basis.

1. Selection of management units: For pilot implementation two subdistricts from each of two separate districts should be selected. Four subdistricts, two districts, and the central office should then be supplied with the necessary hardware and software.
2. User training: Training is critical for the successful implementation of an information system. Users must be informed about the formats and contents of reports and terminal displays and how to request reports. The personnel from the management units selected for pilot implementation should be given appropriate training in the use of the RMDBS.
3. Data collection: All necessary data except the condition survey information already exist in computer files. The condition survey data, if available, should be added to the data base.
4. Evaluation: Evaluation provides the feedback necessary to assess the value of information included in the system. This feedback provides direction for adjustments that may be necessary. First, the adequacy of the software should be evaluated. Ease of use can be taken as an indication of software adequacy. Next, the RMDBS should be evaluated in terms of the information provided. The objective of the RMDBS is to generate information to support maintenance decision making. Therefore, the extent to which information is relevant or not for decision making is the area of concern in evaluating the performance of the RMDBS. This evaluation can be accomplished by systematically interviewing the users in the management units selected for pilot implementation. If management is satisfied with the information system, it is reasonable to assume that the system meets the requirements. If management is not satisfied, modifications ranging from minor adjustments to complete redesign may be required *(8)*.
5. Statewide implementation: After modification, the RMDBS can be generalized for use by all maintenance management units in Indiana.

SUMMARY AND CONCLUSIONS

The most difficult task in the development of an information system is to determine the information requirements of the users. This was done by examining the available data in terms of the functions that were to be performed and by determining who might be interested in different combinations of these data. The major findings of the study are summarized next.

1. When the relationship between level of maintenance and roughness was considered, it was found that the rate of increase in roughness varies inversely with the level of routine maintenance. Because of this relationship, roughness measurements were included in the data base. These measurements could be used by subdistrict management to determine necessary surface treatments.
2. Information on future programmed resurfacing activities was included in the data base. This will help identify highway sections that are scheduled to be resurfaced. Spending on routine maintenance for these sections could be eliminated or decreased.
3. Data collected from condition surveys, suggested by Montenegro and Sinha *(6)*, may be part of the data base. This information can help management at the central office monitor the surface condition of the highway network within a subdistrict on a periodic basis. The same data could be used by subdistrict management to set priorities for performing routine maintenance activities.

After the appropriate information for different users of the RMDBS had been determined, the information was integrated in a data base. Thirty-six application programs were written to provide explicit instructions for physical location of the data elements required to satisfy a particular on-line terminal query or to produce a particular report. The integrated information management system KnowledgeMan was used to reduce the difficulties of manipulating the data contained in the data base.

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The contents of this paper reflect the view of the authors who are responsible for the facts and the accuracy of the data presented herein.

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Performance Evaluation of Jointed Concrete Pavement Rehabilitation Without Resurfacing

DAVID L. LIPPERT

The results of a research project that was conducted to evaluate the effectiveness of concrete pavement restoration (CPR) on jointed portland cement concrete pavement are described. The CPR methods evaluated were pavement grinding, grout undersealing, installing underdrains, retrofitting double-vee load transfer devices, and pavement patching. Five construction sections, located on Interstates in Illinois, were selected for evaluation. The original pavement sections were constructed between 1960 and 1963, then rehabilitated in 1983 and 1984. All pavements were of the same design: a 10-in. slab over a 6-in. granular base and a joint spacing of 100 ft. The evaluation began just before rehabilitation of each section and continued until May 1986. Evaluation was done using crack surveys, destructive testing, and nondestructive testing. Performance factors monitored were faulting, pavement cracking, pavement roughness, skid resistance, deflection, load transfer, void development, and drainage. A great deal of emphasis was placed on grout undersealing and doweled patching in laboratory and field experiments. Effectiveness of undersealing was determined by deflection testing using a Dynatest 8002 falling weight deflectometer and a Road Rater 2008. Another field experiment was conducted to investigate the effects of dowel bar size and number of dowels on full-depth patch performance. Several different techniques for dowel bar grouting were tested in the laboratory to establish grouting procedures. The findings of this research resulted in improvements in full-depth patch design, improved construction procedures, and proper use of undersealing.

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The state of Illinois has many miles of highways composed of jointed portland cement concrete (JPCC). Many of these pavements have approached or are approaching the end of their design life and are in need of major rehabilitation.

Resurfacing with asphalt concrete (AC) is one of the primary methods of rehabilitation used in Illinois. However, asphalt concrete overlays may not be cost-effective for a JPCC pavement that has faulted joints, transverse cracks, and possibly some spalling but is otherwise sound. On this type of pavement, it is possible that rehabilitation without resurfacing can be much less expensive and more cost-effective.

The main objective of this study was to determine whether pavements with faulted joints and transverse cracks or general joint deterioration can be restored by grinding, pressure grouting, placement of underdrains, retrofitting with load transfer devices, or replacement of the joints more economically over the long run than by resurfacing. Five rehabilitation projects