# Rehabilitation of Concrete Pavements by Using Portland Cement Concrete Overlays

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**Overlays of portland cement concrete (PCC) are growing in popularity with paving engineers. This shift away from asphalt to concrete as an overlay material is due in part to some recent shortages in asphalt cement and the concomitant increase in cost of asphaltic concrete materials. Also, some engineers simply prefer concrete surfaces to asphalt for certain applications. PCC overlays are classified as bonded, partially bonded, or unbonded. Within these three classifications are continuously reinforced concrete, jointed concrete, and fibrous concrete overlays. Posttensioned prestressed slabs have also been used as overlays. Not all combinations of overlays and levels of bonding are compatible with all pavement types and all levels of distress. Thus each job must be evaluated as a separate project that uses the appropriate constraints. To evaluate the relative merits of the different types of overlays, a systematic approach to decision making must be used. The limitations and constraints of the different types of PCC overlays are discussed and a possible decision-criterion approach is described for use in evaluating the best overlay alternative.**

Due in part to the increasing cost and in part to spot shortages of asphalt cement, pavement engineers are looking for alternatives to asphalt concrete for rehabilitation of portland cement concrete (PCC) pavements. One method being examined with increasing frequency is a PCC concrete overlay. A number of projects in recent years have demonstrated the economic and technical feasibility of this approach to PCC pavement rehabilitation (1-4). New equipment and technology developed in recent years have provided additional options for PCC overlay construction not available a decade ago, as discussed by Barenberg and Ratterree (5) and by Arntzen in a paper in this Record.

Concrete overlays can be defined and classified in several ways. Among the more obvious and popular classifications is one based on the degree of bond between the overlay and the existing slab, namely, bonded, partially bonded, or unbonded PCC overlays. Within each of these classifications, various types of PCC overlays might be considered, for example, continuously reinforced overlays, plain jointed overlays, reinforced jointed overlays, fibrous concrete overlays, and even prestressed (post-tensioned) concrete overlays. Not all types of PCC overlays are suitable for use with all types of existing concrete pavements. Furthermore, all types of PCC overlays may not be compatible for use with all levels of bond or all levels of distress. For best results, the type of PCC overlay must be matched to the existing pavement structure by type of slab, by condition, and by the degree of bond proposed.

Evaluating the true condition of the existing pavement is one of the most critical factors in selecting the best overlay option. This evaluation should reflect how the existing pavement will affect the behavior and performance of the overlaid pavement. Such an evaluation should be based on structural or behavioral considerations rather than on serviceability considerations.

Closely related to the pavement evaluation are the repairs and rehabilitation of the existing PCC pavements before overlaying. If most existing distress is eliminated prior to overlaying, then the effect of the existing pavement will be different than if the distress had been allowed to remain. Also, the method of repair is a significant factor in evaluating the pavement condition after repair.

Design procedures for PCC overlays have been developed over many years. Most of these procedures are empirical in nature and thus are valid only for the conditions for which they were developed. This leaves the problem of how to design PCC overlays for the new conditions, for which no experience is available.

Finally, after the pavement evaluation and the pavement repairs have been considered, the design procedures applied, and the final decision procedures and criteria implemented, the best PCC overlay must be selected and compared with alternative methods for rehabilitation of PCC pavements. This means careful matching of the advantages and disadvantages of each process and procedure with all others and then making engineering decisions based on facts rather than on personal opinions and biases. Clearly, too many overlay designs or other methods of rehabilitation are selected on the basis of what worked for other pavements rather than on careful selection of the best alternative for the particular job.

The basic concepts and steps outlined above will be expanded on in this paper, and recommendations and procedures for application will be described. Not all procedures described here were applied universally to all the rehabilitation projects described, but these guidelines were adhered to sufficiently to provide inputs for any future designs.

## TYPES OF CONCRETE OVERLAY

Concrete overlays can be classified according to the level of bond developed between the overlay and the existing pavement slab. The three levels of bond generally recognized in this classification are fully bonded, partially bonded, and unbonded overlays. A summary of the three types of PCC overlays, the design procedures used, and the conditions and limitations for each is given in Figure 1 (6). A few comments on these conditions are appropriate here.

### Bonded Concrete Overlay

Bonded concrete pavements are designed by simply determining the additional thickness of concrete needed to carry the anticipated traffic. This is expressed in Figure 1 as

$$T_r = T - T_o \tag{1}$$

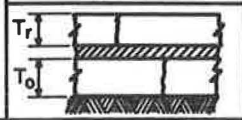
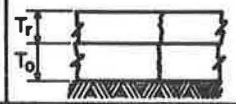
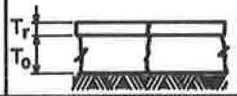
where

$T_r$ = thickness of overlay required,
$T$ = total thickness of PCC slab required for anticipated traffic and subgrade conditions, and
$T_o$ = thickness of existing slab.

In determining the total thickness requirement T, the actual strength of the concrete in the existing slab must be used.

Since only sound existing pavements should be overlaid by using bonded concrete overlays, no condition-correction factor is used in this design.

**Figure 1. Summary of PCC overlay designs for PCC pavements.**

| TYPE OF OVERLAY | UNBONDED OR SEPARATED OVERLAY | PARTIALLY BONDED OR DIRECT OVERLAY | BONDED OR MONOLITHIC OVERLAY |
|---|---|---|---|
| |  |  |  |
| PROCEDURE | CLEAN SURFACE DEBRIS AND EXCESS JOINT SEAL PLACE SEPARATION COURSE-PLACE OVERLAY CONCRETE. | CLEAN SURFACE DEBRIS AND EXCESS JOINT SEAL AND REMOVE EXCESSIVE OIL AND RUBBER - PLACE OVERLAY CONCRETE | SCARIFY ALL LOOSE CONCRETE, CLEAN JOINTS, CLEAN AND ACID ETCH SURFACE - PLACE BONDING GROUT AND OVERLAY CONCRETE. |
| MATCHING OF JOINTS IN OVERLAY & PAVEMENT: LOCATION | NOT NECESSARY | REQUIRED | REQUIRED |
| MATCHING OF JOINTS IN OVERLAY & PAVEMENT: TYPE | NOT NECESSARY | NOT NECESSARY | REQUIRED |
| REFLECTION OF UNDERLYING CRACKS TO BE EXPECTED | NOT NORMALLY | USUALLY | YES |
| REQUIREMENT FOR STEEL REINFORCEMENT | REQUIREMENT IS INDEPENDENT OF THE STEEL IN EXISTING PAVEMENT OR CONDITION OF EXISTING PAVEMENT. | REQUIREMENT IS INDEPENDENT OF THE STEEL IN EXISTING PAVEMENT. STEEL MAY BE USED TO CONTROL CRACKING WHICH MAY BE CAUSED BY LIMITED NON-STRUCTURAL DEFECTS IN PAVEMENT. | NORMALLY NOT USED IN THIN OVERLAYS. IN THICKER OVERLAY STEEL MAY BE USED TO SUPPLEMENT STEEL IN EXISTING PAVEMENT. |
| FORMULA FOR COMPUTING THICKNESS OF OVERLAY ($T_r$) NOTE: T IS THE THICKNESS OF MONOLITHIC PAVEMENT REQUIRED FOR THE DESIGN LOAD ON THE EXISTING SUPPORT C IS A STRUCTURAL CONDITION FACTOR $T_R$ SHOULD BE BASED ON THE FLEXURAL STRENGTH OF | $T_r = \sqrt{T^2 - CT_o^2}$ OVERLAY CONCRETE | $T_r = \sqrt[1.4]{T^{1.4} - CT_o^{1.4}}$ OVERLAY CONCRETE | $T_r = T - T_o$ NOTE: THE ABILITY OF THE OVERLAID SLAB TO TRANSFER LOAD AT THE JOINTS SHOULD BE ASSESSED SEPARATELY EXISTING CONCRETE |
| MINIMUM THICKNESS | 6" | 5" | 1" |
| APPLICABILITY OF VARIOUS OVERLAY TYPES — STRUCTURAL CONDITION OF EXISTING PAVEMENT: NO STRUCTURAL DEFECTS C = 1.0 * | YES | YES | YES |
| LIMITED STRUCT DEFECTS C = 0.75 * | YES | ONLY IF DEFECTS CAN BE REPAIRED | ONLY IF DEFECTS CAN BE REPAIRED |
| SEVERE STRUCT DEFECTS C = 0.35 * | YES | NO | NO |
| SURFACE CRACKS, SCALING, SPALLING AND SHRINKAGE CRACKS: NEGLIGIBLE | YES | YES | YES |
| LIMITED | YES | YES | YES |
| EXTENSIVE | YES | NO | YES |

Bonded concrete overlays must be matched by type to the existing concrete slabs. That is, jointed concrete overlays must be used only on jointed concrete pavements, and continuously reinforced overlays can be used only on existing continuously reinforced concrete slabs. Furthermore, for bonded overlays the existing pavement slabs must be distress-free, since most distress in the existing slab will ultimately reflect through the overlay. Under very special conditions when thick (6 in or more) bonded overlays are used, bonded PCC overlays can be used over a cracked slab provided that the crack in the existing slab is tight and not working. Even then, reinforcing steel is recommended in the overlay across the crack. Obviously, when bonded overlays are used, the joints in the overlay must be matched to the joints in the existing pavement by both location and type.

One of the greatest advantages of the bonded concrete overlay is that a thin overlay can be used. Bonded concrete overlays as thin as 1 in have been used successfully on sound existing pavement, and bonded overlays 2-5 in thick are typical. Advantages of the thin overlays are lower costs and fewer problems in maintaining minimum overhead clearances and matching adjacent facilities. Because of the smaller amount of concrete used with the thin overlay, higher-quality concrete can be specified without significant adverse costs.

With respect to bonded concrete overlays, the proper preparation of the surface is most critical. Obviously, all dirt, grease, and unsound concrete must be removed before the overlay is placed. Some engineers feel that the old surface must be cleaned by removal of the existing surface by cold milling or similar procedures (1). There is evidence, however, that sandblasting and/or hydrobrooming by using water at high pressure (5000-7000 $lbf/in^2$) will adequately clean the surface unless grease and oil have penetrated deep into the existing concrete (1).

Neat cement or cement-sand grouts are used to promote bonding between the existing concrete and the overlay. No special additives are needed when these grouts are used, and they can be spread over the existing surface by using brooms (cement-sand or neat cement grouts) or by using pressure spraying (neat cement grout only). All grouts should be placed on a dry surface just before the fresh concrete is placed.

## Partially Bonded Concrete Overlay

For partially bonded PCC overlays, the thickness design is based on the concept that the existing slab and the overlay act in part as a composite system; those portions of the pavement in which bond was achieved act essentially as a monolithic slab and partially support the portions of the slab that have little or no bond. The thickness requirements for partially bonded PCC overlays are determined from the following empirical relationship, shown in Figure 1:

$$T_r = (T^{1.4} - CT_o^{1.4})^{1/1.4} \quad (2)$$

where T, $T_r$, and $T_o$ are as defined for the bonded PCC overlays. The C-value is a condition index for the existing pavement, which can be defined as follows:

- C = 1.0: no structural defects;
- C = 0.75: limited structural defects; and
- C = 0.35: severe structural defects.

As with the bonded concrete overlay design, the thickness must be determined for the anticipated traffic and support conditions by using the actual strength of the concrete in the existing pavement.

Partially bonded PCC overlays should also be used only on reasonably sound existing pavements, since most cracks in the existing slab will reflect through the overlay within a short period of time. Joints in the existing pavement must be matched by location in the partially bonded overlay.

Surface preparation of the existing concrete is much simpler than it is for fully bonded concrete. The only requirements for partially bonded overlays are that the surface be free of loose materials and that the existing concrete surface be sound. Ideally, the surface should be washed clean of all debris, and paint strips and heavy grease should be removed before overlaying. No grout or special additives are used to promote the bond when partially bonded overlays are used.

Since the partially bonded overlay and the existing pavement are not necessarily monolithic, minimum overlay thickness requirements must be rigidly adhered to. Ideally, the minimum thickness for partially bonded overlays is 6 in, although 5-in overlays have been used successfully. Unless joints are closely spaced, however, significant cracking between joints can be expected when thin partially bonded PCC overlays are used.

## Unbonded Concrete Overlay

Unbonded overlays are intended to be used on existing pavements in which distress is too extensive and too severe to be effectively eliminated before overlaying. A separation course is used between the existing slab and the overlay to prevent the distress in the existing slab from reflecting through the overlay. A big advantage of this type of overlay is that it is not necessary to match the joints between the existing pavements and overlays or even to clean or seal these joints.

Fully unbonded PCC overlays behave eventually as slabs supported by a firm subgrade. Conceivably, one could therefore design an unbonded PCC overlay as a new slab by using the existing pavement only as support and assigning a k-value to the existing pavement. The problem here is one of determining the effective k for the existing pavement.

Unbonded PCC overlays are usually designed according to the following empirical relationship:

$$T_r = (T^2 - CT_o^2)^{1/2} \quad (3)$$

where $T_r$, T, $T_o$, and C are as defined earlier for the fully bonded and partially bonded PCC overlays.

Although the design approach for unbonded concrete overlays is empirical, the basic idea is that the existing pavement serves as a support for the overlay. Consequently, all tipping or rocking slabs should be stabilized by slab jacking or sealed by using heavy rollers to provide a uniform support for the overlay.

The major disadvantage of unbonded PCC overlays is the greater thicknesses required and the concomitant higher costs and greater clearance problems. Minimum thickness for unbonded PCC overlays is 6 in and most overlays will probably be 7 or 8 in thick, depending on the traffic and the condition of the existing pavement.

## EVALUATING EXISTING PAVEMENT CONDITIONS

One of the most confusing aspects of the design of PCC overlays is the problem of evaluating the condition of the existing pavement. According to the design equations shown in Figure 1, the condition of the existing pavement is expressed by a structural condition factor C. This factor varies from 1.0 for an existing pavement in near-perfect condition to 0.35 for a pavement that has a number of shattered slabs. The problem is that this structural condition factor is highly subjective, and only the values of 1.0, 0.75, and 0.35 are used for evaluation of existing pavements.

To determine when major rehabilitation is needed on concrete pavements, some form of serviceability rating system is frequently used (7). This approach to pavement evaluation does not provide the necessary structural information needed to design overlays. In recent years, a pavement condition index has been developed that will provide significant information on the structural health of the pavement (8). This type of information is of great value if rational overlay design processes are to evolve.

Use of nondestructive-testing equipment for evaluating PCC pavements has been suggested (9,10), but these procedures have not been fully developed or effectively implemented. The problem with nondestructive-testing evaluation of PCC pavements is that some pavements that show severe distress, such as D-cracking, due to environmental factors will in fact show excellent results under nondestructive-test loading. Experience shows, however, that such pavements are not good candidates for rehabilitation by using overlays, especially when the existing pavement is expected to carry a significant portion of the load.

None of the evaluation procedures currently in use deal directly with the most serious problems in PCC pavements, namely, the joints. After discussions of the problem of PCC pavement rehabilitation with a number of highway engineers, it became obvious that there was no viable and consistent procedure other than the visual one for determining which joints should be replaced before overlaying, which should merely be resealed, and which should be left untouched. If effective overlay or rehabilitation procedures are to be developed, procedures of evaluating the effectiveness and life of the joints in the existing pavements must be developed.

NEW APPROACHES TO PCC OVERLAY

In recent years, development of new technology and new equipment has provided the means for new approaches to be used with PCC overlays. Specifically, fibrous concrete has been used as an overlay in several locations (7,8,12). Some experiences with fibrous concrete have been good and others have not. The greatest advantage to the use of fibrous concrete rather than plain concrete would be in the reduction of the number of joints needed and elimination of the need to match joints carefully by both location and type between the existing overlay slabs.

Development of cold-milling equipment, which permits the removal of thin strips of the existing PCC surface, has spurred renewed interest in fully bonded PCC overlays (1,5). Cold milling eliminates the need for acid etching and provides a highly reliable bond between the existing PCC slab and the PCC overlay. There are also indications that sandblasting or combined sandblasting and high-pressure water blasting or similar types of surface preparation will result in an equally reliable bond between the two PCC layers without the problem of surface damage to the existing pavement slabs sometimes observed with the cold-milling operations (12).

One of the major problems with fully bonded PCC overlays is reflective cracking. If use of fibrous concrete could eliminate or even greatly reduce the reflective-cracking problem, then this procedure would appear to have great promise as a PCC overlay option. It has been used with only one pavement (Reno Airport), to my knowledge, and has performed well. Additional techniques must still be worked out, however, for how best to handle the joints or cracks in the existing pavement. With the reduction in reflective cracking found by using fibrous concrete, these problems may not be so severe as they are with other types of PCC overlays.

Another example of new developments in PCC overlays is the recent construction of a posttensioned PCC overlay at Chicago O'Hare International Airport, as discussed by Arntzen in a paper in this Record. Several airports in Europe have had excellent experience with newly constructed posttensioned pavements in which the posttensioned slab is placed on a stabilized subbase. The O'Hare project is the first example of the use of a posttensioned slab as an overlay. If the European experience with posttensioned pavements is positive, this could be a viable alternative as a low-maintenance overlay for premium pavements. Cost of this type of construction for rehabilitation would likely preclude the use of posttensioned overlays for any pavements except those on which heavy traffic would justify such cost because of high user cost for down time during maintenance operations. Costs per square yard for the posttensioned overlays are comparable with costs for a new PCC pavement for the same conditions.

In addition to the new techniques for PCC overlays, there are also advances in the technology for repair and rehabilitation of the existing pavements before overlaying. Principal among these developments are the partial-depth patching at joints by cold milling to sound concrete and placing a fully bonded partial-depth PCC patch and new methods for reinstalling effective load transfer across joints and cracks. Lift-out, lift-in procedures for slab replacement have been used in areas of heavy traffic that have high user cost for down time for pavements that have a high volume of traffic (13). Load-transfer devices to reestablish load transfer across existing cracks and joints or to tie the precast slabs to the old pavement have also been developed and are being evaluated (14,15). Leveling of faulted slabs by slab jacking and use of cold-milling equipment is not necessarily new, but this technique is being used with increasing frequency, according to several highway engineers consulted recently.

These are but a few of the new concepts and procedures being used in the rehabilitation of PCC pavements. No doubt other procedures could also be found. The point is that there is much room for ingenuity and engineering innovation in the area of pavement repair and rehabilitation. As more of our high-volume PCC pavements experience distress and with the increasing cost of conventional methods of rehabilitation by using asphalt concrete, it is likely that more innovations will be developed. The engineer should be aware of such developments and use them when these newer approaches can make PCC pavement rehabilitation more effective.

DECISION CRITERIA

Too frequently, the decision as to which type of rehabilitation to use is based on the least initial cost. Since there is an increasing number of heavy-volume PCC pavements that need rehabilitation and increasing pressure for getting the most for our rehabilitation dollar, it is necessary to develop added criteria and procedures for selecting the best overlay and rehabilitation scheme.

There are a number of factors that can affect the decision as to which pavement rehabilitation technique is best suited for any given pavement. These factors vary for different pavement and traffic conditions and for different levels of distress. Factors that might be considered in such an evaluation process include initial cost, average annual cost, design reliability, future traffic disruption and maintenance efforts, construction duration, energy consumption, and others.

Some of the factors that affect the design decisions are subjective and difficult to quantify. To relate the suitability of each alternative for a particular project, a ranking system can be developed similar to that outlined in the Federal Highway Administration's Value Engineering for Highways (16). In this approach, each evaluation or decision factor is assigned a value from 0 to 100 to reflect its relative importance in the final decision. Some factors and their relative importance are listed below. It is important to note that the relative importance value (RIV) for each factor may change from project to project.

| | RIV | |
|---|---|---|
| Factor | Project 1 | Project 2 |
| Initial cost | 25 | 20 |
| Avg annual cost | 20 | 20 |
| Design reliability | 20 | 20 |
| Construction duration | 15 | 20 |
| Pavement manageability | 10 | 5 |
| Energy consumption | 5 | 0 |
| User inconvenience during construction | 5 | 15 |

Table 1 shows how the various alternatives can be ranked by using this system. For each alternative, each factor is assigned a rating based on this factor's standing among all alternatives. For example, for initial cost, the alternative that has the highest initial cost will be assigned a zero rating and the alternative that has the lowest initial cost will have a rating of 100. These ratings are then multiplied by the RIV for each factor. By summing the products of the RIV and the rating value for all factors for each alternative, the numerical ranking of each alternative is deter-

Table 1. Calculation of ranking for three alternatives.

| Factor | RIV | Project A Amount | Rating | Ranking | Project B Amount | Rating | Ranking | Project C Amount | Rating | Ranking |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial cost ($) | 25 | 10 437 | 0 | 0 | 8 709 | 52 | 13 | 7 159 | 100 | 25 |
| Avg annual cost ($) | 20 | 510 000 | 40 | 8 | 442 150 | 90 | 18 | 427 950 | 100 | 20 |
| Design reliability | 20 | - | 80 | 16 | - | 70 | 14 | - | 30 | 6 |
| Construction duration (days) | 15 | - | 100 | 15 | - | 100 | 15 | - | 20 | 3 |
| Pavement manageability | 10 | - | 90 | 9 | - | 50 | 5 | - | 20 | 2 |
| Energy consumption (billion Btu) | 5 | 204 | 0 | 0 | 89 | 75 | 2.5 | 50 | 100 | 5 |
| User inconvenience | 5 | - | 20 | 1 | - | 70 | 3.5 | - | 90 | 4.5 |
| | | | | 49 | | | 71.0[a] | | | 65.5 |

[a]Best alternative.

mined. The alternative that has the highest summation will be the most desirable alternative.

Obviously, the above procedure is not a precise calculation, but it is interesting to note that when engineers apply this technique, they frequently come up with the same final answer even though there was no coordination in the RIV or the rating values assigned. Furthermore, it is not unusual that the best alternative arrived at in this manner is not the same as the alternative the engineer would have chosen without the evaluation. But when asked how the evaluation should be changed, no one has any suggestions and all usually agree that the alternative indicated by the procedure is probably the best one.

Perhaps the best feature of this approach to decision making is that it forces the engineer to consider all factors involved in these decisions in a rational manner. If a systematic procedure is not used, some factors are often forced into the background and not properly taken into account in the final decision.

## SUMMARY

The use of PCC overlays is a viable method for rehabilitating existing PCC pavements. However, there are a number of types of PCC overlays (bonded, partially bonded, and unbonded overlays) that may be subdivided as to type of pavement. Not all types of PCC overlays are suitable for use with all types of existing PCC pavements. Also, the level and density of distress in the existing pavement may severely limit the options available to the designer.

Because of the number of options available, all PCC rehabilitation plans should start by making a careful evaluation of the existing pavement. Such evaluation should include the support conditions of the existing pavement and the structural condition of the existing slabs. When the existing conditions of the slab are evaluated, particular attention must be given to the condition of the joints, especially to their load-transfer efficiency. Parts of the above evaluations can be made with nondestructive-testing equipment and thorough visual inspections of the pavements by trained observers.

Finally, after all data on the existing conditions have been gathered, the designer should make the necessary decisions as to which of the overlay options are or are not valid because of existing pavement conditions. Such decisions must by necessity include the two options of repairing the distress in the existing pavements first or of not repairing it. With these two options, alternative rehabilitation programs should be developed that consider all valid overlay design approaches.

To ensure a careful consideration of all factors, a systematic approach to the evaluation of all overlays should be taken. The approach shown here is one scheme that can be used. Other schemes may also be effective. The important point is to use some logical scheme in the decision-making process so that all factors are properly considered.

Finally, the design engineer should be alert for any and all improved procedures for rehabilitating PCC pavement. All pavement rehabilitation requires innovative engineering.

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# Pavement Management Study: Illinois Tollway Pavement Overlays

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**Since 1967, when Byrd, Tallamy, MacDonald and Lewis (BTML) performed the original pavement maintenance study for the Illinois State Toll Highway Authority, there have been major changes in the characteristics of the highway, volume of traffic, and in the pavement composition itself. Several studies have provided information to update the original maintenance and rehabilitation program, and the study reported here has created a continuity in this process. As the result of the comprehensive pavement evaluation by BTML, data have been accumulated on current conditions of serviceability, slipperiness, surface defects, and deflection. These factors were considered individually as well as collectively to provide recommendations for improvements or rehabilitation. Current pavement condition was determined through visual and instrument surveys to provide present-serviceability-index factors and computations, traffic and axle-load analyses, and skid numbers for each of the three tollways in each direction. The visual pavement deficiencies—cracking, patching, faulting, and pumping—on rigid pavements were addressed by the visual survey. The instrument survey was concerned with the determination of roughness, skidding, and deflection data. Pavement condition was determined through the study of traffic volume, lane distribution, axle load, and the number of axle repetitions. Cumulative 18-kip single-axle loads were determined for the tollway. An integral part of a pavement management system is an adequate data base. The evaluation performed by BTML compiles the data necessary to create a format adaptable for use in an effective pavement management system for the tollway. The pavement management framework is a management tool to aid consistency and optimization in the decision process. It is designed to expand decision-making capability as well as to provide necessary feedback on these decisions.**

The Illinois Tollway consists of three toll highways--the Tri-State, East-West, and Northwest Tollways, as illustrated in Figure 1. Together they total approximately 243 centerline miles, of which 104 miles have three traffic lanes in each direction. In addition to the main-line mileage, the Illinois Tollway consists of several access ramps, interchanges, and toll-collection facilities. The Illinois Tollway is a high-level system that serves motorists in the metropolitan Chicago area as well as throughout the state of Illinois. Segments of the tollway system serve more than 100 000 vehicles daily, which includes Interstate transport and localized commuter travel.

Management decisions are made as a part of normal daily operations for an active highway system such as the Illinois Tollway. The pavement evaluation and rehabilitation criteria provided as a part of this study are intended as management tools to aid the decision maker. They are designed to improve the efficiency and consistency of the decision-making process.

Current pavement-rehabilitation needs are in part a function of management decisions made in the past. Likewise, decisions made today will have an impact on future pavement-rehabilitation needs and, consequently, costs.

## HISTORY OF PAVEMENT EVALUATION

The American Association of State Highway Officials (AASHO) Road Test conducted near Ottawa, Illinois, during 1956-1961 produced basic concepts about the evaluation of existing pavement conditions and the relationship of a pavement service life to the number of axle loads to which it is subjected.

Realizing the importance of this approach to the prediction of pavement service life, tollway officials in 1967 engaged Byrd, Tallamy, MacDonald and Lewis (BTML) (then Bertram D. Tallamy and Associates) to evaluate long-range pavement-maintenance needs for the tollway system. As part of that study, a detailed pavement condition survey was conducted on the entire tollway system. One of the principal purposes of the field inspection was to obtain the factual data required for the serviceability-index equation developed at the test road.

In the application of road-test equations to the tollway, it was necessary during 1967 to undertake a comprehensive study of traffic. This was required to estimate the characteristics and amount of traffic that had used the road between each interchange section since it had been opened. Similarly, extensive axle-load computations were made to determine the number and magnitude of axle loads. Pavement design and present-serviceability-index (PSI) values were then used to plot the service-life curves for each average PSI section between major interchanges. The year at which the pavement is estimated to reach a terminal serviceability condition (TSI) was determined from these curves.

The need existed to extend and make slight modifications to the service-life curves developed during the 1967 study because of the environmental and traffic effects on the tollway pavements. Also, there was a need to develop new service-life curves for those pavement sections that had been resurfaced since 1967. The tollway engaged BTML to perform the necessary observations, measurements, calculations, and analyses to adjust these curves and extend the resurfacing schedule in 1969, 1971, and 1975.

More than 20 years have passed since the original pavement evaluation, and major changes have occurred in both the composition and the volume of traffic on the tollway, as well as in the pavement structure itself. For a comprehensive pavement evaluation, skid data and structural-strength data are obtained in addition to serviceability indices and a visual survey in 1979.

Figure 2 illustrates the study approach for the