Resurfacing of Plain Jointed-Concrete Pavements

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In 1975, the Georgia Department of Transportation placed a 1-mile concrete overlay test section on I-85 north of Atlanta, which has a high volume of truck traffic. The test area consists of 7.6-cm (3-in) continuously reinforced concrete (CRC), 11.4-cm (4.5-in) CRC, 15.2-cm (6-in) CRC, and a 15.2-cm (6-in) portland cement concrete (PCC) overlay. The primary objective was to determine the performance of various concrete overlay systems over a faulted jointed-concrete pavement. Some 16 asphaltic concrete overlay sections that had various thicknesses and treatments were placed adjacent to the PCC section in 1976. The performance obtained to date has indicated the importance of treatment of the existing pavement prior to placement of an overlay. Stabilization of moving slabs, replacement of fractured slabs, and patching and spall repair of the existing pavement are essential to the performance of the overlay. In addition, a level platform must be provided by grinding at the joints or by placement of a leveling course to prevent the overlay from being locked into the existing pavement by the faulted joints. Both 15.2-cm CRC and PCC sections, which have 4.6-m (15-ft) joint spacing, are performing well at this time. The 15.2-cm thickness of concrete overlay should be considered minimum for resurfacing over concrete when there is heavy truck traffic. The results from the asphaltic concrete test sections indicate that the use of a waterproofing membrane or fabric with a 10.2-cm (4-in) asphaltic concrete overlay will reduce the occurrence and the severity of reflection cracking from the underlying joints.

The Interstate system is nearing completion nationwide, and already many sections constructed 10 years ago or more are in need of major repairs or overlays. Many states are faced with the problem of how most effectively to upgrade existing plain jointed-concrete pavements that are suffering structural deterioration. The entrance of water through joints and cracks, the presence of erodible or compressible subgrade materials, and heavy load applications combine to cause nearly all distress in plain jointed-concrete pavements.

Yearly condition surveys made on Georgia's plain jointed-concrete pavements show that deterioration accelerates as the volume of truck traffic increases. Approximately 75 percent of the Interstate mileage in Georgia, or 1352 km (840 miles), is concrete pavement; 1078 km (670 miles) is plain jointed concrete.

Some of the older plain jointed-concrete pavements in Georgia are more than 15 years old, and many areas were in need of major repair or overlays. Many sections of Georgia's Interstate system have been rehabilitated or resurfaced or are currently being scheduled for upgrading. Since 1975, the Georgia Department of Transportation has initiated several research projects to find answers to the problems of rehabilitation techniques, water intrusion, overlay methods, and overlay thicknesses. The results of the concrete-overlay research project initiated in 1975 in Georgia are presented here and the asphaltic concrete-overlay test project will be discussed briefly for comparison purposes.

CONCRETE OVERLAYS IN GEORGIA

The first concrete-overlay project in Georgia was constructed in 1973. This project is a continuously reinforced concrete (CRC) overlay over an existing jointed-concrete pavement in the southbound lane of I-75 that extends from SR-42 near Forsyth to approximately milepost 175 near Macon for a total length of 21.9 km (13.6 miles). The original pavement consisted of portland cement concrete (PCC) 22.9 cm (9 in) thick that has expansion joints at 183-m (600-ft) intervals and contraction joints at 9.1-m (30-ft) intervals. This project is approximately 4.8 km (3 miles) long. The next 11.3 km (7 miles) of the original pavement is PCC 20.3 cm (8 in) thick that has 9.1-m joint spacing and expansion joints at 9.1-m intervals. The remainder of the original pavement section is a 25.4-cm (10-in) PCC pavement that has 9.1-m joint spacing over a 20.3-cm soil aggregate base in which the top 7.6 cm (3 in) is stabilized by using bituminous material. A CRC overlay 20.3 cm thick was placed from SR-42 to I-475 and had a steel content of 0.6 percent. From I-475 to the end of the overlay project, a distance of 4.5 km (2.8 miles), a CRC overlay 17.8 cm (7 in) thick was placed that had a 0.7 percent steel content.

No preparations were made to the original pavement and no attempts were made to bond the overlay to the original pavement or to provide for a positive bond breaker or stress-relief interlayer. Average daily traffic (ADT) levels on this section of I-75 currently are 30 000 ADT from SR-42 to I-475 and 13 500 ADT from I-475 to the end of the overlay.

The area that has the 17.8-cm overlay looks excellent; it has tight cracks and normal cracking patterns. The exception is near the bridge approaches, where the cracks appear to be somewhat wider and some closely spaced interconnecting cracking occurs. In these areas, the old concrete was removed prior to placing the CRC overlay to allow for a transition from the overlay to existing bridge decks.

The 20.3-cm CRC overlay in the area that has the higher traffic volume and that was placed over the 25.4-cm PCC pavement generally has normal cracking patterns that include fairly tight cracks. This section is generally in good condition; there are some Y-cracks and cluster cracking.

The cluster cracking is more pronounced and more extensive on the overlay section placed over the project that contained the 22.9-cm PCC that had the expansion joints. Some patching has been done in this area related to poor consolidation at construction joints. Wide transverse cracks are also present in this section and are thought to be related to the expansion joints, since the wide cracks are straight across the roadway and appear at regular intervals. The cluster cracking is probably occurring over the old joints in the original pavement. Overall, this project is in good condition. The overlay has recently been ground to restore the surface texture from SR-42 to I-475.

Research-Overlay Project

In 1975, an ad hoc committee that consisted of members from the American Concrete Paving Association, the Associated Reinforcing Bar Producers, the Portland Cement Association, and the Wire Reinforcement Institute published a report that described the results of a condition survey made on various CRC overlay projects nationwide. This survey showed that good results could be expected from CRC overlays that had a minimum thickness of at least 15.2 cm (6 in). Since no data were available on the performance of relatively thin CRC overlays, the Georgia Department of Transportation decided to place several concrete-overlay test sections that ranged in thickness from 7.6 cm to 15.2 cm.

A 1.6-km (1-mile) concrete-overlay test section was placed in November 1975 on I-85 in Gwinnett County 48.3 km (30 miles) north of Atlanta. This portion of I-85 was among the worst in Georgia in terms of faulting and broken slabs. The design characteristics and pavement condition of the existing pavement at the time of placement of the overlay are shown below:

Design Feature
- Pavement thickness: 22.9 cm
- Subbase: 20.3-cm soil aggregate; top 7.6 cm stabilized with cutback asphalt
- Joint spacing and design: 9.1-m undoweled
- Shoulder: cement-treated soil aggregate with asphaltic concrete shoulder

Performance
- Age: 15 years
  - ADT
    - 1975: 17 200, 32 percent trucks
    - 1977: 20 000, 34 percent trucks
    - 1980: 21 500, 31 percent trucks
- Faulting: 2.5 mm or more, 83 percent; 5 mm or more, 29 percent
- Cracked slabs: 8 percent

This 1.6-km test section was divided into 400-m (0.25-mile) test areas and there was a short transition between each test area. The test sections selected were 7.6-cm CRC, 11.4-cm (4.5-in) CRC, 15.2-cm CRC, and 15.2-cm plain jointed-concrete pavement that used dowels and both 9.1-m and 4.6-m (15-ft) joint spacing.

Pavement preparation prior to overlay construction consisted of undersealing slabs, replacing broken slabs, and repairing and leveling the shoulder. The pavement was tested by using both static and dynamic loads and a Dynaflect, and slabs that experienced excessive movement were undersealed. Broken slabs were removed and replaced without the use of dowels. Curing compound was applied prior to paving in an attempt to break the bond between the old and the new concrete pavements.

Southbound traffic was diverted to the northbound lane through use of slip lanes across the median. Signing, delineation devices, and increased law-enforcement visibility were used; as a result, no accidents occurred during construction and traffic flowed satisfactorily.

During construction, measurements of concrete depth were taken frequently. In general, all aspects of construction of these test sections were closely monitored by research, laboratory, and construction personnel.

Construction of Test Section

The first test section placed was the 15.2-cm plain concrete pavement; dowels were placed over every old transverse joint. One-half of the section had joints sawed at 9.1-m intervals that matched the old joints, whereas the other half of the section had 4.6-m joint spacing. Transverse joints in this section that did not match an old joint were not doweled. The dowel bars were placed in baskets and were 2.9 cm (1.125 in) in diameter, 45.7 cm (18 in) long, and placed 38.1 cm (15 in) center to center. The dowels were coated with red lead paint for corrosion protection, and the dowel-bar assembly was anchored to the existing pavement. An open-cell neoprene joint sealant was used in the transverse joints. The longitudinal shoulders were sealed by using a hot-poured sealant.

The second test section placed was a 15.2-cm CRC pavement that had 34 no. 5 longitudinal bars, a total steel percentage of 0.6 percent. The steel was placed on chairs at the request of the contractors. The steel was lapped 50.8 cm (20 in) at the splices at a 30° angle. A 1.9-cm (0.75-in) transverse-doweled expansion joint was placed between the 15.2-cm plain concrete pavement section and the 15.2-cm CRC section.

The third test section placed consisted of 11.4-cm CRC pavement that had 40 no. 4 longitudinal bars, a total steel percentage of 0.6 percent. The bars were also placed on chairs in this section. A short transition section was placed between the 15.2-cm and the 11.4-cm CRC sections. The steel from both sections was carried through the transition.

The fourth and final section placed was a 7.6-cm CRC pavement that used 2.44x9.75-m (8x32-ft) woven wire-mesh mats for reinforcement. Three mats were placed over the two 3.66-m (12-ft) lanes. The welded wire-mesh openings were 10.2x30.5 cm (4x12 in) in D7.2 by D4 size steel. The welded wire fabric was lapped a minimum of 61 cm (24 in) over existing transverse joints. The wire mesh was supported on chairs spaced approximately 137 cm (4.5 ft) apart. A short transition section was placed between the 11.4-cm CRC section and the 7.6-cm CRC section. The reinforcing steel continued through the transitions to tie the CRC sections together.

The depth of the overlay for each section was controlled by a string line because of the settlement of many of the slabs. The actual overlay depth therefore is somewhat more than the design thickness in many areas.

Shoulder Construction

All sections contained concrete shoulders tied to the main-line pavement by tie bars spaced 76.3 cm (30 in) apart. No key was provided at the pavement edge. The width was 3.05 m (10 ft) for the outside shoulder and 1.22 m (4 ft) for the inside shoulder.

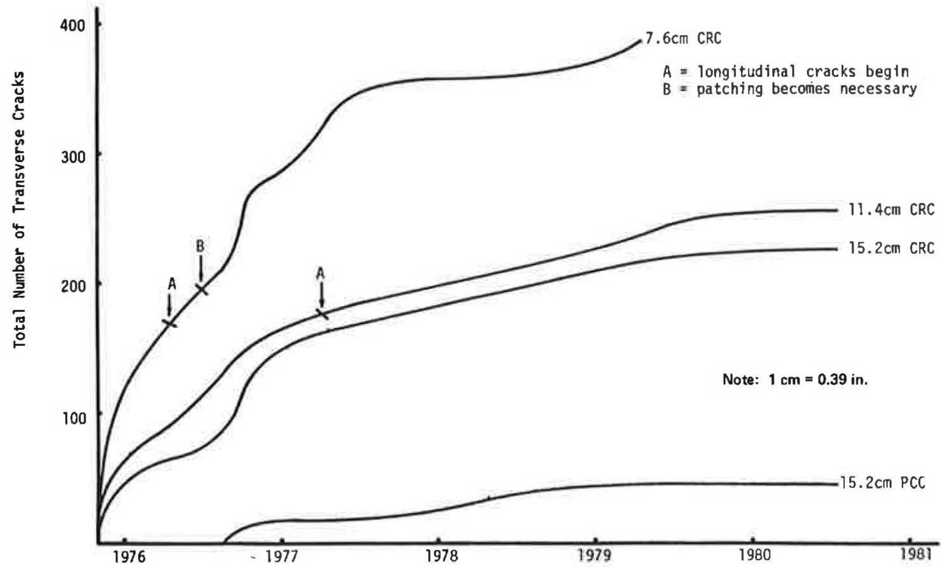
The 15.2-cm plain, 15.2-cm CRC, and 11.4-cm CRC sections had plain concrete shoulders and joints sawed at 9.1-m (30-ft) spacing that matched the location of the contraction joints in the old pavement. Rumble strips were provided in the shoulder to encourage the motorist to stay on the main-line pavement.

The shoulder in the 7.6-cm CRC test section was a welded wire-mesh reinforced shoulder tied into the main line by using tie bars. This shoulder also contained the rumble strips that were formed during the paving operation.

Construction Problems

Construction problems encountered on this project were confined to the 15.2-cm plain concrete overlay and the 7.6-cm CRC overlay. The dowels used in the plain concrete overlays were placed in baskets and attached to the existing surface by using nailed clips. Soon after construction had begun, it was evident that the basket assemblies were moving. At times a basket assembly would be displaced several centimeters and sometimes by as much as a meter. It was first thought that an insufficient number of clips was used to hold the basket assemblies down. Additional clips were added to the remaining basket assemblies. The additional clips seemed to stop most of the basket movement, but the outer two dowels on the baskets were still being moved forward. An inspection of the paving equipment revealed that the minimum opening of the paver was 716.3 cm (23.5 ft) and that the basket assemblies were 716.3 cm wide. The basket assemblies had been contacting the paver, which pulled them forward. Adjustments were made, and no further problems with dowel-basket movement occurred. However, this adjustment was not made until the 15.2-cm plain concrete test section had been nearly completed.

Figure 1. Crack progression in concrete-overlay test project, I-85, Gwinnett County.



Some problems were encountered with the placement of the 7.6-cm CRC test section. These problems were minor and caused no structural damage to the overlay. The combination of thin overlay depth and placement of both reinforcing mesh and shoulder tie bars at middepth caused these problems. The reinforcing mesh and shoulder tie bars had to be carefully arranged to maintain adequate concrete cover.

Performance of Concrete Overlay

The performance evaluation of the test section consists of visual observations of the condition, mapping of all cracks, deflection measurements, and movement measurements across the joints and cracks in the overlay sections at regular intervals. The appearance of the cracks and the cracking patterns have given the best information with respect to performance to date. Deflection measurements are highly dependent on temperature; deflections obtained early in the morning are generally much higher than those obtained later in the day, due to curling of the underlying pavement.

Hairline cracking appeared in the CRC overlay sections several days after placement of each section. These hairline cracks were always located directly over the old contraction joint and occurred over each construction joint with no exceptions. The progression of additional cracking always occurred near the joints within 30-60 cm (12-24 in) of the original crack. A crack survey was conducted two months after completion of the project; it showed that in the 7.6-cm CRC section, multiple cracking of two cracks or more was present over 65 percent of the old construction joints compared with 50 percent for the 11.4-cm section and 34 percent for the 15.2-cm section. The occurrence of cluster cracking as well as the number of cracks in the cluster decreased with the thickness. This trend was reinforced during subsequent performance evaluations. The progression of the total number of cracks in the CRC test section can be seen in Figure 1.

As the CRC cracking progressed, the next cracks tended to occur approximately midway between the underlying joints (midslab). These cracks emanate from the sawed centerline joint and progress to the shoulder.

Further crack progression results in multiple transverse cracks near the underlying joints, additional midslab cracks, and the development of longitudinal cracks. Short longitudinal cracks develop that interconnect the multiple transverse cracks over the underlying joints and generate punchouts in the 7.6-cm CRC test section.

The 7.6-cm CRC section has progressed through all the steps mentioned above. Extensive cracking, punchouts, and patches exist in the 7.6-cm CRC section. Approximately 20 percent of the areas over the underlying joints in the 7.6-cm CRC section have required patching.

It was evident during the patching operations that all the transverse and longitudinal cracking occurring in this section was located over the steel in the reinforcing mats. This fact indicates excessive stress from the concrete, probably caused by deflection at the joints of the underlying PCC pavement.

The 11.4-cm CRC section has multiple cracks over the underlying joints, midslab cracks have progressed, and longitudinal cracks have appeared and are progressing. No major patching has been necessary, but some edge punchouts are present in this section, which indicates initial structural failures.

The 15.2-cm CRC overlay has shown very good performance to date. One or two cracks occur soon after construction and are associated with the underlying joint. Midslab cracks occur, but multiple cracking near the underlying joint and longitudinal cracks are minimal.

The 15.2-cm PCC overlay that has 9.1-m joint spacing has had cracking in approximately 65 percent of the overlay slabs. This high percentage of slab cracking could be attributed to inadequate bond breaking between the overlay and the existing pavement. Differential slab curling between existing and overlay pavement could cause the cracking.

The 15.2-cm PCC overlay that has 4.6-m joint spacing has had 30 percent of the overlay slabs cracked or broken. The majority of the cracked overlay slabs that have 4.6-m joint spacing occur at the beginning of the project, where problems occurred with movement of the dowel-basket assembly.

ASPHALTIC CONCRETE OVERLAYS

We are mainly concerned here with the performance of unbonded concrete overlays for jointed-concrete pavements. For comparison purposes, a description of the design and performance of the asphaltic

Table 1. Cracking in overlay, southbound lane, I-85, Gwinnett County, June 1980.

Treatment Before Overlay[a]	Asphalt Concrete Overlay					
	5.1 cm		10.2 cm		15.2 cm	
	Reflection Cracking (%)	Severity of Cracking[b] (%)	Reflection Cracking (%)	Severity of Cracking (%)	Reflection Cracking (%)	Severity of Cracking (%)
Bituthene	87	44	57	17	0	0
Mirafi	100	80	60	24	4	1
Petromat	98	71	57	22	18	4
Edge drain	100	93	98	78	66	29
Control	100	98	95	62	24	7

Note: 1 cm = 0.39 in.
[a]Arkansas base (16 percent and 6 percent) was also used.
[b]Length of transverse cracking reflected through overlay as percentage of total length of transverse joints.

concrete test sections located adjacent to the PCC sections is now included.

Sixteen asphaltic concrete overlay test sections were placed in 1976 to compare the performance of this type of overlay with the performance of the CRC and PCC test sections. The major variables in the asphalt test sections were three overlay thicknesses--5.1 cm (2 in), 10.2 cm, and 15.2 cm--and various treatments prior to placement of the overlay. These treatments consisted of the placement of two different engineering fabrics (Mirafi and Petromat), the addition of edge drains, the placement of a stress-relieving interlayer referred to as "Arkansas Base" that consists of large, one-size stone held together by using bituminous liquid, and the placement of strips of a heavy-duty waterproofing membrane (Bithuthene) over all existing joints and cracks. Control sections in which none of the above treatments was used were also placed with each overlay thickness. All treatments were repeated with each of the three overlay thicknesses. A 372-$N \cdot m^2$ (70-$lbf \cdot yd^2$) leveling course was placed in addition to the overlay.

The performance is evaluated mainly in terms of the number and severity of reflection cracks from the existing joints into the overlay. These data are shown for June 1980 in Table 1, which indicates that the various treatments have had a significant effect in reducing the rate of occurrence of reflection cracking and in reducing the severity of the cracking, especially with the 10.2-cm and 15.2-cm thicknesses. Based on the early results from these test sections, the Georgia Department of Transportation has for the past three years been including the heavy-duty waterproofing strips in all projects on the Interstate system where asphaltic concrete overlays (normally 10.2 cm) were placed over existing jointed PCC pavement.

TREATMENT OF EXISTING PAVEMENT

The results to date of the test sections point out that the preparation of the existing pavement prior to placement of the overlay is of utmost importance if excellent performance of the overlay, whether it is asphalt or concrete, is to be obtained. The various treatments that can be used to prepare the existing pavement are (a) stabilizing moving slabs by means of undersealing, (b) addition of edge drains, (c) replacement of fractured slabs, (d) patching of spalls, and (e) resealing of open or wide joints and placement of a waterproofing membrane if an asphalt overlay is to be used.

One of the most important factors in the success of an overlay is to provide a stable platform on which to place the overlay. If this is not done, distress in the form of excessive cracking and eventual punchouts will occur in a short time in the overlay. When a slab is stabilized, it must be recognized that lifting must be avoided in order not to create voids in another area of the pavement. All fractured slabs should be replaced, since they represent a structural failure in the pavement and will likely create problems in the overlay in the future. In the same manner, spalls and small failures should be repaired if the distress is severe. Under no circumstances should it be relied on for the overlay to bridge over problem areas in the existing pavement if an economical overlay thickness is to be used. Edge drains are frequently added to a pavement as a rehabilitation measure to remove infiltrated surface water. The experience in Georgia to date on rehabilitation projects has showen that edge drains are not effective on a long-term basis for the prevention of pumping and faulting. The test sections on the I-85 overlay project that used edge drains have a significantly higher incidence of joints that show reflection cracking than do the other sections for the 15.2-cm asphalt concrete overlay area (Table 1). This difference is not as apparent in the sections that use the other overlay thicknesses because of the high percentage of reflection cracking that is present in all these test areas.

CONCLUSIONS

1. The performance of the overlay on I-75 shows that a thick, partially bonded CRC overlay can be placed over a PCC pavement with excellent results. The thickness of the overlay, however, may not be economically feasible for most projects.

2. The results to date of the test project on I-85 indicate that in order to obtain good performance of a relatively thin unbonded concrete overlay, the existing pavement must be properly prepared (undersealed, broken slabs replaced, patched, etc.). Furthermore, placing curing compound as a bond breaker when faulted joints are present is not sufficient since the overlay is locked into the expansion and contraction movements of the underlying joints. The overlay should be placed on a flat horizontal plane, which can be established by grinding the joints flush or by placing an asphaltic concrete leveling course. A bond breaker should then be placed prior to placement of the overlay.

3. Multiple cracking in the CRC overlay over the existing joints will occur if moving slabs are not stabilized. All distress found on the 7.6-cm CRC overlay section is occurring over old joints. This type of distress is also likely to occur in time with thicker CRC overlays.

4. The performance of the concrete shoulders on the overlay project has been excellent. Concrete shoulders should be used when a concrete overlay is placed.

5. The 7.6-cm CRC section has not provided acceptable performance and is not considered a

suitable rehabilitation measure for plain jointed PCC pavements.

6. From the current condition of the test section, the 11.4-cm CRC section could perform acceptably for up to 10 years with some maintenance. This overlay design could be used successfully on sections that have moderate traffic levels if the existing pavement was properly prepared.

7. The minimum thickness for a concrete overlay on a road that has a large volume of heavy trucks should be 15.2 cm. Both the CRC and jointed PCC sections that used the 15.2-cm thickness are doing well after five years of heavy truck traffic. From the performance of the two PCC overlay sections on I-85, the joint spacing in a 15.2-cm jointed PCC overlay should be 4.6 m. All the joints in the original pavement should be matched in the overlay and intermediate joints added to obtain the desired joint spacing. The transverse cracking that occurs on the test sections is attributed to the movement of the dowel assemblies and other start-up problems at the time of construction of these short test sections. These problems are not expected to occur on a regular construction project.

8. The major problem with using concrete overlays is the necessity of closing the roadway and diverting the traffic for an extended period of time. Generally the traffic will have to be directed onto the adjacent travel direction, which requires temporary concrete median barriers and upgrading and widening of the shoulders to maintain two lanes of traffic in each direction on an undivided highway or construction of slip ramp on a divided highway. This additional expense must be considered in determining the cost of a concrete overlay. From the standpoint of accidents and traffic flow, the slip ramps used on the research-overlay project performed very satisfactorily. This performance was felt to be due to proper design of the slip ramp to minimize loss of speed by the driving public, to signing, and to delineation between opposing lanes of traffic.

9. The experience in Georgia to date on the overlay sections reported here and on other rehabilitation projects has shown that edge drains are not effective on a long-term basis for the prevention of pumping and faulting.

10. In the asphaltic concrete overlay sections, the placement of strips of heavy-duty waterproofing membrane (Bithuthene) over all joints and cracks in the existing PCC pavement has proved to date to be the most effective method of reducing the number and severity of reflection cracks from the existing joints into the overlay. Engineering fabrics (Mirafi and Petromat) and the stress-relieving interlayer (Arkansas base) were also effective. The edge-drain treatment was not effective; in fact, it was worse than no treatment (control sections).

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Design Procedure for Premium Composite Pavement

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A brief description of a method for designing premium composite pavements is given. A premium pavement is defined as a pavement structure that will perform free from structural maintenance for 20 years and will require only minimum maintenance for an additional 10-20 years. To satisfy this requirement, the procedure incorporates the best current design and construction practices for composite pavement. The method described provides highway engineers with a systematic technique for selecting a premium pavement design. The procedure is more complex than some empirically based systems but is relatively easy to use. The complete manual includes a number of charts, figures, and worksheets and a procedure for their use. On the basis of design data, a user can select a precalculated pavement cross section from a catalog of designs. An overview of the design system and a brief explanation of the procedure and of the factors considered in the development of the procedure are given. An explanation of the design inputs required for use of the procedure is also included. A discussion of the limiting criteria used in development of the design procedure for premium pavement is followed by special considerations required for the design of reinforcement in the concrete layers of composite pavements and discussion of the design methodology.

For several years, the Federal Highway Administration (FHWA) has pursued multiple research studies aimed at producing premium pavement structures for heavily traveled highways. The intention of these efforts has been to develop pavements and minimize maintenance, which disrupts traffic flow and creates hazards and high user costs. This research is aimed at the development of pavement structures that will be maintenance-free for a minimum of 20 years and will require only routine maintenance for 10-20 years thereafter. A composite pavement has, in this case, been defined by FHWA as a pavement made up of both rigid and flexible layers and that has an asphaltic surface layer. The rigid layer(s) may be portland cement concrete (PCC) or cement-treated soil or base.

The research reported here is drawn from a portion of an FHWA-sponsored research project on flexible and composite structures for zero maintenance. The overall goal of that project is to develop pavement design procedures that can be used to design the thickness, specify the materials, and specify the unique construction procedures required for premium flexible and composite zero-maintenance pavements.

In using the design method for composite pavements discussed here, we emphasize that sound engineering must also be used in selecting any pavement design strategy. The designer must recognize that it is difficult in a general design procedure to successfully couple the knowledge of performance of local materials and the service requirements for