CONCRETE OVERLAYS FOR CONCRETE AND ASPHALT PAVEMENTS

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Concrete resurfacing of worn concrete pavements has been a fairly common practice in the United States for more than 60 years. Since the mid-1950's new construction on the Interstate System has taken precedence, and fewer concrete resurfacing projects were built. With the emergence of the 3R program of pavement rehabilitation, restoration and resurfacing, new interest is being shown in the use of concrete as a more durable and permanent resurfacing material. A recent survey (1977) of 39 concrete resurfacing projects in the U.S. with plain or conventionally reinforced designs showed them ranging from 4 to 36 years of age, with an average age of 25 years. Their designs varied considerably; more than a third of the projects were plain concrete without reinforcement or dowels. The results of a 1975 survey of 23 CRC projects are reviewed and brought up to date with 1980 condition data. Designs using a thin layer of concrete bonded to the old slab have been employed as a resurfacing method in the U.S. for many years. The results of bridge deck resurfacing using a dense concrete mix have been particularly successful. The resurgence of interest in concrete pavement resurfacing has brought new emphasis on techniques and equipment to adapt this method to the level of other full-scale high speed paving operations. Current concrete resurfacing activities in the U.S. show a noticeable trend toward the use of concrete overlays to restore worn bituminous pavements.

Concrete resurfacings are not new in the United States. They go back more than 60 years. The first recorded project was built in 1916 in the State of Michigan. It was just 75 mm (3 in.) thick and used triangular mesh reinforcement. Most early projects were quite heavily reinforced and were generally 75 to 150 mm (3 to 6 in.) thick. They were built to reinforce and make more rideable the narrow pavements originally laid of brick, block or concrete. Starting with the 1916 project, the next 40 years saw many concrete resurfacing projects built throughout the country. One of the earliest publications of the Portland Cement Association on resurfacing was written in 1930--a half century ago--and listed 41 projects already in service in 21 states. The project list assembled for a 1955 revision numbered 310 projects in 28 states. Bibliography No. 21 of the Highway Research Board, published in 1957 and supplemented in 1963, lists 214 separate articles describing concrete resurfacing projects built to that time.

After the mid-1950's and the beginning of the Interstate System, there was less emphasis on resurfacing and more concentration on new construction. However, some agencies continued to build concrete overlays, with the result that there are a number of projects with a range of ages and designs to furnish a basis for performance evaluation and comparison. The projects in service were surveyed, some in 1975 and others in 1977, and the condition of most of these was observed again during this past year. This paper will report on the performance of the major types of concrete overlays that have been used over both concrete and asphalt pavements, including:

-- plain and conventionally reinforced concrete
-- continuously reinforced concrete
-- bonded concrete
-- fiber-reinforced concrete

Before discussing performance of the different resurfacing designs, it is necessary to review briefly the characteristics of each. Concrete overlays are discussed in more detail in the PCA publication "Guide to Concrete Resurfacing Designs and Selection Criteria."(1)

Types of Concrete Overlay Designs

The degree of bonding between overlay and existing pavement provides three categories of design: bonded, unbonded, and direct.

Bonded Concrete Resurfacing

With fully-bonded resurfacing, measures are taken to ensure a complete bond to the existing pavement so the overlay becomes an integral part of the slab. Bond is generally obtained through the use of a sand-cement or neat cement bonding grout applied to the base pavement after it has been scarified or roughened in order to ensure a

good bond. Bonded overlays are generally much thinner than unbonded resurfacing, being usually 50 mm (2 in.) or 75 mm (3 in. thick). Bonding is necessary for thin overlays, but has also been used for layers as thick as 8 in. on airports. The existing concrete must be in sound structural condition, but can have some surface distress such as shrinkage cracks, spalling, and scaling. Existing joints must be matched and surface preparation is critical. Surfaces are scarified to remove unsound concrete, exposed reinforcing steel is thoroughly cleaned, and a bonding grout is applied. Until recently, the extent of this preparatory work was considered prohibitive for long stretches of highway. Thus, its use was confined primarily to airport pavements and to bridge decks where the extra expenditure for more careful control could be justified. In the late 50's and early 60's a number of bonded overlays were built on World War II Air Force base pavements. A report on the performance of these overlays will be presented at this conference.

In recent years, the milling, planing, and grinding of pavements have taken on a renewed importance, with new machines developed to advance this technology. Consequently, removal of surface concrete has changed from a time-consuming and costly operation to a routine one. With this change, the concept of thin-bonded overlays has become more attractive for highways.

While they also add strength, most thin-bonded resurfacings are placed for the purpose of restoring an adequate riding surface. Bonded layers have also been used to increase the pavement thickness to the required design depth for traffic anticipated during its life. Design considerations for bonded layers differ from those used in thicker unbonded resurfacings. The requirements to insure positive bond between old and new concrete take precedence over all other design factors.

Another paper at this conference will discuss bonded resurfacings in more detail.

Unbonded and Direct Overlays

With unbonded overlays, a separation course is used to prevent the overlay from bonding to the existing pavement. This lack of bond also minimizes reflection cracking. In the case of distorted or broken pavement, a separation course also serves as a leveling course to minimize overrun of concrete resurfacing materials. This design has also been used in overlaying pavements with severe joint deterioration due to D-cracking or alkali aggregate reaction.

A direct overlay is used where the question of whether and to what degree bonding takes place is not critical to the performance of the resurfacing. In this method, the new overlay of concrete is placed directly on the old pavement and the layer is designed to act to some degree as an integral unit with the base slab. No special attempt is made either to obtain bond or to break it. Joints in the overlay must be directly over or within one foot of joints in the underlying pavement, and intermediate joints in the overlay may need to be provided where the base pavement is a reinforced design with long panels.

Direct overlays are used only when the existing concrete pavement is in sound, well-seated condition, with no major distress, distortion, or rocking slabs. They have been used extensively on airport pavements, where original pavement and planned resurfacing thicknesses are usually greater and slabs more fully restrained.

Advantages of plain and reinforced unbonded and direct resurfacings of a minimum thickness, usually 125 mm (5 in.) are:

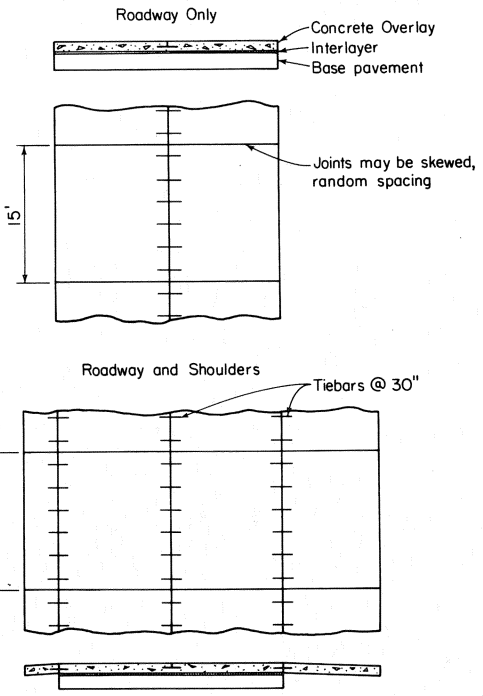
1. They can be built with conventional paving methods and equipment.
2. They can be used over broken or distorted pavements.
3. They are built to a thickness range that is a proven design in full-depth concrete pavements.

Resurfacings that are not bonded to the base pavement may be designed as either plain, conventionally reinforced, continuously reinforced, fiber reinforced, or prestressed slabs:

Plain Concrete. This design contains no steel reinforcement and is jointed at close intervals to control cracking. (Fig. 1)

Plain concrete designs are particularly applicable where the pavement to be resurfaced is in sound condition with no structural breaks or extensive cracking. Where a direct overlay is used, the short joint spacing allows the freedom to match joints in place and to place intermediate joints between them as required to control cracking. Most projects of this design include an interlayer where the base pavement is concrete. With the use of an interlayer, matching of joints in old and new concrete is not critical. Dowels at joints are included in the design where the volume of truck traffic warrants additional load transfer, or in channelized traffic areas on airport pavements where dowels would be required in new full depth pavement.

Figure 1. Design for unbonded plain concrete resurfacing for highway pavements.



Conventionally Reinforced Concrete (Fig. 2). This overlay design has distributed steel in the slab panels and dowels across all transverse joints. The presence of properly designed steel mesh in this design serves to inhibit early cracking, and tends to hold these cracks tightly together if and when they form. This design is particularly applicable where unstable subgrade, frost action, swelling soils, or other stresses have caused erratic cracking in the existing pavement that might reflect through the resurfacing layer.

Continuously Reinforced Concrete (CRC) (Fig. 3). CRC overlay design uses a layer of concrete containing continuous longitudinal steel reinforcement and no transverse joints. The design depends on the steel to hold tightly together the closely-spaced transverse cracks that form in a random pattern in the slab. Crack spacing should be ideally .6 to 2.4 m (2 to 8 ft) in order that continuity in the form of shear transfer is obtained across the cracks. Transverse steel may or may not be a part of the design.

Prestressed Concrete. Overlays in which prestressed concrete is used are relatively uncommon in the U.S. One experimental project was completed on an airport apron at San Antonio, Texas in 1955, and a second short project was built in 1980 on an airport runway at O'Hare International Airport, Chicago. The method, which has been used extensively for airport pavements in Europe, uses overlay design details and construction methods similar to those used in full depth prestressed pavements.

Figure 2. Design for unbonded conventionally reinforced concrete resurfacing for highway pavements.

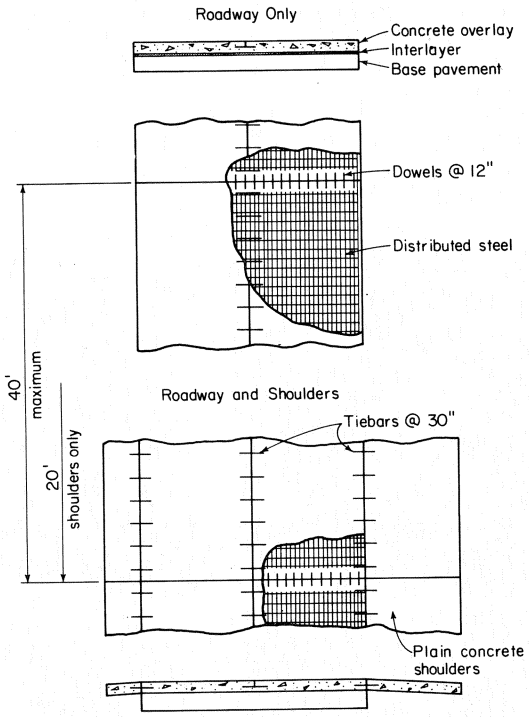
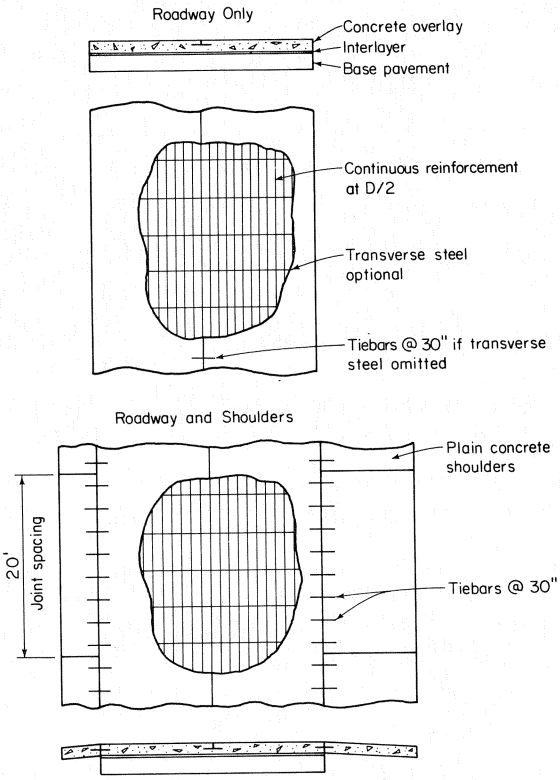


Figure 3. Design for unbonded continuously reinforced concrete resurfacing for highway pavements.



Design requirements for thickness, jointing, reinforcement and interlayer are discussed briefly below for the most frequently used unbonded designs.

Thickness. Concrete resurfacing thickness design has been based on equations developed originally by the Corps of Engineers. They have been used extensively since their introduction, particularly for airfield pavement. The resulting thickness may be somewhat less than those considered practical to build for highways.

While there is no generally accepted overlay thickness design method, several agencies have continued development efforts in this area. An excellent review of current evaluation and overlay design concepts is contained in a recent TRB publication.(2) A resurfacing design method that includes both jointed and continuous concrete overlays and both bonded and unbonded interfaces has recently been published for FHWA.(3) The procedure consists of three basic steps:

1. Evaluation of existing pavement by means of condition survey and deflection measurements.
2. Determination of design inputs, including projected traffic, environmental considerations, and materials properties.
3. Overlay thickness analysis to satisfy fatigue cracking criteria with stresses and strains in the pavement computed by linear elastic layered theory.

Improved equipment for measuring pavement deflections (Dynaflect, Falling Weight Deflectometer, etc.) and the development of modern computers for more rapid and sophisticated analysis of data promise to make this method a realistic and practical solution to future overlay design. At least one paper at this conference will be devoted to the subject of resurfacing design.

CRC overlay design methods recommended in the past(4) have included a thickness reduction factor to take account of the lack of joints and full load transfer across cracks in the CRC design. AASHTO Interim Design Guide revisions now being considered would eliminate any thickness reduction factor for CRC pavements based on their performance history. This revision would presumably also apply to CRC resurfacing and, if adopted, would specify no reduction in thickness as a result of the presence of continuous steel.

The recommended minimum design thickness to be used for unbonded or direct overlay designs is 125 mm (5 in.) for plain and conventionally reinforced concrete, and (150 mm) (6 in.) for CRC regardless of traffic.

Jointing. Unbonded resurfacings of plain or conventionally reinforced design should be jointed to match the underlying pavement where a direct overlay is used. Where an interlayer is used to break bond, this requirement may be waived and the resurfacing layer jointed independently without regard for the base pavement jointing pattern.

In plain concrete resurfacing using an unbonded or direct overlay design, transverse contraction joints are spaced at intervals not exceeding 4.6 m (15 ft) where dowels are not used, and a maximum of 6.1 m (20 ft) where dowels are a part of the design to furnish additional load transfer. They may be skewed and randomized as with full-depth designs. Depth of transverse joints should be a minimum of 1/4 the resurfacing thickness.

In conventionally reinforced overlay design, transverse joints should have a spacing not greater than 12.2 m (40 ft) and a depth of at least 1/4 the overlay thickness.

Longitudinal hinged joints in all unbonded overlay designs should be provided at spacings of approximately 3.7 m (12 ft) to conform to the design of the underlying pavement. Depth of these joints should be not less than 1/3 the resurfacing thickness.

Reinforcement. With conventionally reinforced concrete overlays, reinforcement is in the form of welded wire fabric distributed throughout each panel. Dowels are added across joints for increased load transfer capacity. The amount of steel reinforcing used varies with slab length and thickness, friction between overlay slab and interlayer, and working stress of the welded wire fabric.(5)

The minimum percentage of longitudinal steel in CRC resurfacing recommended by the Associated Reinforcing Bar Producers is 0.6%, with an increase to 0.7% suggested in northern climates having extreme low temperatures, large seasonal temperature variations, and heavy salting policies. Use of transverse steel is optional, but should be considered where longitudinal cracks are present in the slab being overlaid.

Interlayer. For unbonded designs, a layer of material with well-defined bond-breaking characteristics should be used between old pavement and new resurfacing. This reduces the chances for reflective cracking from the base slab, and permits the use of a different pavement design or jointing arrangement in the resurfacing from that used in the original pavement. Interlayers may include such varied materials as polyethylene sheeting, liquid curing compound, bituminous coatings with a sand blotter, and machine-laid hot-mix asphalt.

Where the base pavement is rough or in poor vertical alignment, the interlayer may also serve as a leveling course to provide a uniform interface with the concrete and a constant overlay thickness.

Concrete Overlays on Asphalt. Any of the designs used in unbonded or direct overlays also apply where concrete is used to overlay existing asphalt pavement.

Within recent years, projects using plain concrete designs on asphalt have been built on the Interstate System, on secondary roads, and on airports to overlay worn flexible runways, taxiways, and aprons.

Concrete overlays for asphalt pavement are designed in the same manner as for normal concrete pavements. The k value of the flexible material on the roadway is determined from deflection measurements taken on its surface. Concrete overlays over asphalt on the Interstate system have been built 200 to 275 mm (8 to 11 in.) thick. Most of the concrete overlays on asphalt on the secondary system have been a minimum 125 mm (5 in.) and a maximum 175 mm (7 in.) thick.(6)

Plain concrete overlays on asphalt are normally jointed at intervals of 4.6 m (15 ft) for undoweled, 6.1 m (20 ft) for doweled design, or placed with a skewed randomized jointing arrangement. Joint design and spacing requirements for plain and reinforced overlays are similar to that needed for new pavements, with the asphalt pavement acting in the same role as a stabilized subbase under a new pavement. Normally, no interlayer is needed where concrete is placed directly on the old asphalt surface. Cold milling of the surface of asphalt base pavements is now routinely possible with recently developed lane-width milling machines. This method may be an economical alternative to placing an interlayer of asphalt over a rough or distorted flexible pavement.

Fiber Reinforced Concrete Overlays. The concept of reinforcing concrete with randomly distributed fibers has received major emphasis only in about the last decade. Field testing has been done on fibers of steel, glass, plastic and asbestos, with steel the most commonly used in pavement resurfacing applications. Fiber-reinforced overlays built to date have included both thin bonded layers and thicker independent layers placed over existing pavements.(7) Early projects in which fiber-reinforced concrete was used as a resurfacing have shown the importance of matching the joints in the base pavement. Fibers are generally 25 to 63 mm (1 to 2-1/2 in.) long, and either round, flat, or deformed in cross-section. They are introduced into the concrete mix during batching, in rates up to 2-1/2% of the mix volume. On most pavement resurfacing projects to date, the fiber mix has been placed directly on

the old pavement, without an interlayer, whether concrete or asphalt.

Concrete Overlay Performance - U.S. Projects

With that brief review of the general design of concrete overlays, we will now look at how these designs have performed in this country.

As mentioned earlier, the CRC overlay projects in service were surveyed in 1975, and the plain and conventionally reinforced overlay projects were surveyed in 1977. The results are reported in two publications available from PCA or from the other associations cooperating in the surveys.

This discussion, which will bring up to date the information in these surveys, will also include the performance to date of several newer projects that were put in service since the surveys. It will look first at the 1977 survey since it included the older projects and some of the earlier overlay designs used on our highways in this country.

a) Plain and Conventionally Reinforced (Unbonded)

The joint PCA-American Concrete Paving Association survey of plain and conventionally reinforced concrete overlays in 1977(8) included all concrete resurfacings that could be located on state highway systems in the U.S. Thirty-nine projects were found that were still in service. They are listed in Table 1.

Project ages varied between 4 and 36 years. The majority had service lives in excess of 20 years. Many of these projects, such as the 125 mm (5 in.) plain concrete project in Georgia on State Route 21, were and still are in excellent condition.

In addition to the nearly 40 projects which were found where the concrete resurfacing was still exposed and carrying traffic, another 43 projects were located that had been overlaid with asphalt. These projects had service lives averaging over 20 years before the asphalt overlay was placed.

Because most concrete resurfacing projects presently in service were built prior to the Interstate System and therefore are about 25 or more years old, Table 1 includes a wide variety of designs that represent the level of expertise and experience that had been gained up to that time. Many resurfacing designs included integral widening of the old pavement, a practice that may not be applicable on today's wider pavements. Designs varied in the requirements for an interlayer or separation course between old slab and resurfacing. Where used, various materials included layers of sand, granular foundation course or mine tailings, asphalt emulsion coatings with or without a sand blotter course, and machine-laid hot-mix asphalt.

Plain Undoweled Design. Plain concrete resurfacings without dowels or reinforcement have given excellent service in California. They have been used to bring old four-lane pavements up to Interstate structural standards, and to increase freeway capacity by matching new resurfacing to new full-depth lane additions. As a result, many projects are more than 150 mm (6 in.) thick and performance of some projects has been enhanced because resurfacing is on the inside lighter-traffic lanes of multiple-lane freeways. Even where such favorable circumstances do not prevail, performance has been excellent under substantial volumes of heavy traffic. None of the projects exhibit major distress manifestations at this time. Maintenance requirements have been minor, and serviceability ratings have remained high.

The plain designs used on projects in other states in the survey also showed similar good performance with ages of 24 to 30 years.

Reinforced Short Panel Design. This design evolved from 23 years of concrete resurfacing experience in Iowa, with concurrent development in Nebraska. During the period between 1949 and 1954, Iowa built 16 projects of this design, totaling about 144 km (90 two-lane miles) of concrete resurfacing. Three of these projects, totaling 32 km (20 miles), are still in service. Of the other 13 that have been overlaid with asphalt, such overlays occurred at ages of 13 to 15 years on 5 projects and 19 to 24 years on 8 projects, with an average age of 19 years. The design included a 150 mm (6 in.) resurfacing thickness and a .9 m (3 ft) integral widening 250 mm (10 in.) thick on each side, cast with the resurfacing and tied to it with substantial steel (No. 4 bars 1.2 mm (4 ft) long at (365 mm) (14-1/2 in.) spacing). The full-width, welded-wire fabric was supplemented with a No. 4 bar placed longitudinally 225 mm (9 in.) from the outer edge of the widening and just below the mesh. Sawed contraction joints 38 mm (1-1/2 in.) deep were at 4.9 m (16-ft 4-in.) spacing, with every fifth joint a premolded bituminous strip 1/8x2-1/2 in. placed during construction for crack control. No dowels were used at joints, and no interlayer was employed between old and new concrete.

This undoweled reinforced short panel design resulted in considerable distress on projects in Iowa with high truck counts. In most cases, the thicker integral widening rested on a subgrade-subbase combination that was placed to a higher density during construction than was present in the material in place under the base pavement. Where this difference in subgrade density was substantial, it was theorized that the widening was subjected to greater expansion and frost heave. The upward heave lifted the resurfacing slab off the base pavement, and soil and sand were pumped between the two slabs from the base under the widening and shoulder. This waterborne material was deposited under the approach slab at the joint, and extensive major faulting resulted.

The Nebraska design was substantially the same as that used in Iowa, with minor changes in mesh weight and joint spacing. Nebraska's projects with this design are in excellent condition after 26 and 28 years.

Short reinforced panel design was used in early resurfacing designs to overcome the effects of cracks and structural breaks in the old pavement that could cause reflective cracking in the resurfacing. The increased steel quantity was specified to allow omitting an interlayer, and perhaps to more nearly balance the interior slab design with the thicker 250 mm (10-in.) monolithic widened section.

Reinforced Long Panel Design. Projects using long joint spacings 12.9 to 30.5 m (43 to 100 ft) and mesh reinforcement without dowels at the joints were found only in the State of Michigan. Most projects were 125 mm (5 in.) thick; most used a relatively thin bituminous emulsion separation course between slabs. Nearly all included integral

Table. 1. Plain and Conventionally Reinforced Concrete Resurfacing Projects in Service - 1977

Location	Underlying Pavement	Overlay Thickness (in.)	Age (Yr)	1977 Condition
Plain Undoweled Design				
CA I-8	PCC	6	9	Very Good
CA I-5	5-1/2 in. AC	8.5	4	Good
CA I-5	AC on CTB	6	9	Very Good
CA 163	PCC	6 and 8	7	Very Good
CA US101	AC	7	11	Very Good
CA US99	AC	7	13	Very Good
CA US99	PCC and AC	7 min.	6	Very Good
CA US99	AC on PCC	8	18	Very Good
CA US99	AC on PCC	8	21	Very Good
CA I-80	PCC	8	9	
CA I-5	PCC	8	11	Good
CA US91	AC	8	11	Very Good
CA US99	7 in. & 9 in. PCC	9	18	Very Good
GA SR21	6 in. PCC	5	30	Good
MI Dye Rd.	Old Asphalt	8	24	
IN Delaware St.	6 in. PCC	6	26	
IN Morris St.	8 in. PCC	8	27	
Reinforced Short Panel Design				
IA US6	10-7-10 PCC	6	25	Fair
IA US61	10-7-10 PCC	6	23	Good
IA US34	10-7-10 PCC	6	23	Good
NB US6	9-6-9 PCC	5 and 6	28	Very Good
NB US6	9-6-9 PCC	5 and 6	26	Very Good
NC US29	PCC	7	25	Fair
Reinforced Long Panel Design				
MI US127	9-7-9 by 20 ft PCC	6	24	Fair
MI M-97		5 min	25	Fair
MI M-19	8 in. by 22 ft PCC	5 min	29	Fair
MI Eliz. Lk. Rd.	7 in. by 16 ft PCC	5 min	27	Fair
MI M-29	18 ft PCC	6	23	Good
MI I-69 (temp)		6 min	20	
MI US131-M-60	18 ft PCC	6-8	24	
MI US31	16 ft PCC	5	27	
Reinforced Doweled Design				
MO SR82	6 in. PCC	4	29	Good
MO US71	PCC	5	36	Fair
NB US6-34	PCC	5	13	Good
MI M-21	18 ft PCC	5	25	Fair
MI Packard test track	6 in. PCC	6	31	Good
Miscellaneous Unclassified Design				
IA Ashworth Rd.	10-7-10 PCC	5 min	14	Very Good
NC US70		5	23	Fair
TX US82		6 min	31	

Note: 1 in. - 25.4 mm, 1 ft - .305 m

widening of .3 to .9 m (1 to 3 ft) on each side, and most had joint spacing of about 30.5 m (100 ft.) Only one project is known to have had dowels at the joints for load transfer.

The 8 Michigan projects with reinforced long panel design are still wholly or partially in service with ages from 23 to 29 years. Records of 14 other projects that were subsequently overlaid with asphalt show an age range of 12 to 38 years at time of overlay, with an average age of 21 years. Most of the projects in service show some distress -- cracks, spalls at joints, or patched areas. In spite of these shortcomings, the relatively thin, undoweled long panel design, which might be considered inadequate by today's standards, has an excellent longevity record.

Conventional Mesh-Dowel Design. Resurfacing designs using both mesh and dowels were used in five projects in midwestern states. Thickness varied from 100 to 150 mm (4 to 6 in.), and joint spacings from 9.2 to 30.0 m (30 to 99 ft). Traffic was not heavy on these projects, but 100 mm (4-in.) and 125 mm (5-in.) thickness in Missouri showed remarkable longevity of 29 and 36 years, while in Michigan 125 mm (5-in.) and 150 mm (6-in.) overlays with bituminous interlayers had ages of 25 and 31 years. All projects surveyed were in fair to very good condition.

The 1977 survey report also listed resurfacing projects of plain and reinforced designs constructed since those shown in Table 1, but which had no significant performance history at the time of the survey. During 1980, the performance of each of these projects was reviewed. Their present condition is shown in Table 2, which also includes recent projects of these designs built since the survey was made.

b) Continuously Reinforced (Unbonded)

To check on the performance of CRC resurfacing, a survey was made in 1975 of 23 projects in 11 states.(9) Basic data on these projects are listed in the survey report. Traffic on these projects ranged from a low of 1,500 vehicles per day to 42,000 vpd. The service lives of the projects at the time of the survey ranged from 1 to 16 years. About half of the total sections shown were built 150 mm (6 in.) thick. Only two projects, both of them experimental, used thicknesses less than 150 mm (6 in.).

The percentage of longitudinal steel in the projects surveyed ranged from 0.45 to 1.0, with most at 0.6%.

Transverse bars were omitted on two projects. Neither had longitudinal cracking in the resurfacing and both were rated as excellent in 1975.

Results of the 1975 survey showed that 94% of the total miles was rated excellent to good, and 6% of the mileage was rated poor in 1975. Poor ratings were attributed to one or more of the following factors:

- -- Non-uniform thickness of the overlay where a leveling course was omitted and the base slab was irregular or settled;
- -- Poorly consolidated concrete resulting from improper vibration of concrete under closely spaced steel;
- -- Inadequate subgrade drainage; high water table with no provision for adequate edge drains;
- -- Non-uniform base pavement support and failure to stabilize original pavement in known problem areas.

During 1980, the condition of each of the CRC overlays that had been surveyed five years earlier was determined, and this information is shown in Table 3. The results show that the condition of some projects in freeze-thaw regions has deteriorated. On others, little change has taken place in their condition over the five year period.

Since the 1975 survey, additional CRC overlay projects have been constructed. These are shown in Table 4.

c) Bonded Concrete Overlay Performance

Table 5 shows the major projects built with bonded concrete during the past decade. As seen from this table, the State of Iowa has been the most active innovator in the U.S. in the use of bonded resurfacings. Their successful "Iowa Method" of constructing bonded bridge deck resurfacings had demonstrated that bond could be obtained with a scarified, clean, dry surface of old concrete using a grout coat of cement, sand, and water. Whether these techniques could be adapted to larger highway projects with higher production rates was the question that prompted experimental projects in 1976, in 1977, and again in early 1978. Their most recent project -- a full scale, non-experimental resurfacing of a 8 km (5-mile) section of I-80 in western Iowa in 1979 -- placed a 75 mm (3-in.) bonded resurfacing over a CRC pavement.(10)

The performance of bonded overlays on highways in Iowa has been generally excellent. The state has developed improved test methods for determining bond strength, and in most cases the degree of bond attained has been greater than that required for good performance. Grout coat materials and mix composition have been studied, and innovations in application methods put into practice. Experiments in repairing damaged joints by installing deeper concrete sections at joint locations that are placed integrally with the overlay are performing successfully to date. New approaches in scarifying, placing and jointing have been developed, and the body of knowledge concerning bonded concrete overlay design and placing is growing with each passing year.

d) Fiber-Reinforced Overlay Performance

The final tabulation in this series is Table 6, showing information on fiber-reinforced concrete overlays built in the U.S. on airports, streets, roads and parking areas since 1971.

Performance of these projects has ranged from very poor to very good. Where performance has been substandard, the cause has often been tied to construction difficulties. Fibers have been shown to increase toughness and ductility and resistance to crack propagation in the concrete. It is these qualities that have enhanced its consideration for use as a resurfacing material, and it will no doubt continue to find application where special overlay requirements are involved.

Current Overlay Project Examples in the U.S.

Since this is essentially a performance report on concrete overlays, mention should also be made of several projects built within the past two

Table 2. Plain and Conventionally Reinforced Concrete Resurfacing - Recent Projects

Location	Underlying Pavement	Overlay Thickness (in.) & Type	Year Built	1980 Condition
CA Rte 163	AC	9 P	1977	Excellent
GA I-85	PCC	6 P	1975	Excellent
ID I-80N	AC	7 P	1980	New
IL Manteno Rd.	PCC	6 P	1971	Good
	AC	" P	"	Excellent
IL Plank Rd.	AC	5 min P	1974	Excellent
IN Anderson St.	PCC	4-3 R	1976	Fair
	"	4 P	1976	Poor
IA US 30	PCC	5 P	1973	Very Good
	"	4 R	"	Good
IA US 20 Dallas Co.	AC	5 min P	1977	Excellent
IA US 20 Washington Co.	AC	5 min P	1977	Excellent
IA US 20 Boone Co.	AC	5 min P	1977	Excellent
IA I-80	AC	10 PD	1979	New
KS US 24	PCC	6 P	1978	Excellent
MI Hines Dr.	PCC	5 min P	1979	New
MN TH 71	PCC	5-1/2 P	1977	Excellent
UT I-80N	AC	9 P	1976	Excellent
UT I-80	AC	10 P	1979	New
UT I-80	AC	10 P	1980	New
UT I-80	AC	11 P	1980	New

Note: 1 in. = 25.4 mm; P = plain, R = reinforced, PD = plain doweled

Table 3. CRC Overlays - Projects Built Prior to 1975 Survey

Location	Underlying Pavement	Overlay Thickness (in.)	Year Built	Overlay Condition 1975	Overlay Condition 1980
AR I-55	PCC	6	1972	E	E
GA I-75	PCC	7	1971	E	E
	"	8	"	E	G
IA US30	PCC	3	1973	E	G
	"	4	"	E	G
IL I-70	PCC	6	1967	E	VG
	"	7	"	E	VG
	"	8	"	E	VG
IN I-69	PCC	6	1970	P	P
IN I-69	PCC	6	1971	P	VP
MD I-70	PCC	6	1972-4	E	E
MD I-83	PCC	6	1973	E	E
MS I-20	PCC	6	1971	E	E
ND I-29	PCC	6	1974-5	E	P
ND I-29	PCC	6	1972	G	P
OR I-5, 80, 205	AC	7-9	1969-75	E	E
TX I-35	PCC	6	1965	E	E
TX I-35W	PCC	6	1965	E	E
TX I-40	AC	8	1972	E	E
WI US16	PCC	6 min	1973	E	G

Note: 1 in. = 25.4 mm
E = excellent, VG = very good, G = good, P = poor, VP = very poor.

Table 4. CRC Overlays - Projects Built Since 1975 Survey

Location	Underlying Pavement	Overlay Thickness (in.)	Year Built	1980 Condition
AR I-55	PCC	6	1980	New
CN I-86	PCC	6	1975-6	Excellent
I-86	PCC	6	1978-9	New
GA I-85	PCC	3	1975	Poor
		4.5	"	Good
		6	"	Excellent
OR I-80	AC	7-9		Excellent
PA I-90	PCC	7	1975	Good
PA I-90	PCC	7	1976	Good
TX I-610	PCC	8	1975	Excellent
I-45	PCC	6	1976	Excellent
WI I-94	PCC	8	1980	New

Note: 1 in. = 25.4 mm

Table 5. Bonded Concrete Resurfacing - Recent Projects

Location	Thickness (in.)	Year Built	1980 Condition
IA US20 Waterloo	2	1976	Good
IA US20 Clayton Co	2-5	1977	Good
IA US20 Sioux City	3	1978	Good to Fair
IA I-80	3	1979	New
IA Indianola St.	2	1979	New
IL Champaign AP	8	1978	Excellent
NY US12 Utica	2	1979	New

Note: 1 in. = 25.4 mm

Table 6. Fiber-reinforced Concrete Overlays

Year	Location	Thickness (in.)	Base Pavement
1971	U.S. Corps of Engrs. WES	4	10 in. PCC
1971	Ohio DOT, I-71	4	Truck weigh sta., bit. agg. base
1972	Iowa, Cedar Rapids	3	Street, taxiway, bridge deck
1972	Florida, Tampa AP	4,6	Taxiway, 10 in. concrete
1972	Michigan DOT, Detroit	2,3	Urban arterial street concrete
1973	Iowa, Greene Co.	2,3	Lt. traffic road, concrete
1973	Texas, I-10, Beaumont	3-3½	Existing PCC
1974	Texas, Ft. Hood, U.S. Army	4	Tank parking, bituminous
1974	Minnesota DOT, TH 51	2,3	Trunk highway, concrete
1974	New York, JFK Airport	5-1/2	Runway end, bituminous
1975	Nevada, Reno Airport	4	Apron, 11 in. concrete
1976	Nevada, Las Vegas Airport	6	Parking apron, bituminous
1977	Florida DOT, US 41	2	Test road, composite pavement
1977	New York, La Guardia Airport	6	Parking apron, bituminous
1977	Virginia, Norfolk NAS	5,7	Aprons, bitum. resurfaced PCC

Note: 1 in. = 25.4 mm

years whose performance will be watched with a great deal of interest. Three projects used bonded concrete, one is a plain concrete resurfacing, and two designs were for concrete overlays on asphalt.

1. The first was a 75 mm (3 in.) bonded overlay placed on a 13 year old 200 mm (8 in.) CRC pavement on an Interstate route in Iowa. It was the first time bonded concrete has been used on a major Interstate project, the first use of bonding on CRC, and the first time bonding has been used where D-cracking was present in the underlying concrete. The project should furnish much good information for the future.
2. A second bonded project was in the State of New York where a 50 mm (2 in.) resurfacing was applied to 10 locations in a 9.6 km (6 mi.) project on a primary highway where scaling had damaged the pavement surface due to a lack of air-entrainment. The project is a good example of the modern approach to pavement surface repair.
3. The third bonded project placed a 50 mm (2 in.) thick layer of new concrete over the top of a 30 year old 18.3 m (60 ft) wide city street whose surface had deteriorated from deicing chemicals. The project restored a durable surface to the pavement while retaining the esthetic characteristics and low maintenance advantages of the original pavement.
4. A 1979 project in Michigan used a plain concrete overlay, and also included widening and tied concrete shoulders. The 125 mm (5 in.) minimum thickness overlay upgraded an old narrow park drive and was placed over a previous asphalt overlay that was left in place on the existing pavement.
5. The State of Utah has rehabilitated several lengths of asphalt Interstate Highway by overlays of plain concrete. Thickness of the overlay is usually 225 mm (9 in.) or more, and full depth concrete shoulders tied to the mainline overlay slab have been part of the design.
6. A new and innovative method for restoring worn asphalt pavements was introduced in Iowa in 1979. The construction sequence first removed a 7.3 m (24 ft) width of the old asphalt to a depth of 225 mm (9 in.) in three passes of a cold-milling machine. A 250 mm (10 in.) thick plain concrete pavement with doweled joints at 6.1 m (20 ft) spacing was then slipformed into the trench thus formed. Asphalt shoulders were retained on both sides and brought up to grade by adding an inch of new asphalt surface. Where depth of original asphalt plus subsequent overlays is substantial, in this case 325 mm (13 in.), the introduction of the lane-width milling machine has made this unique "inlay" method a practical alternative to conventional concrete overlays of asphalt.

Summary

We believe that concrete resurfacing is a practical means of extending the service life of existing pavements, whether asphalt or concrete, without major reconstruction. Our surveys in recent years have shown that with proper attention to detail, concrete resurfacings with a number of different basic designs can be built to last more than 20 years. Such length of service life, coupled with reasonable first cost and minimum maintenance requirements, should result in life-cycle costs that are lower than those for resurfacings that require multiple surface renewals over the same time period. These lower costs will be accompanied by the additional advantages of a higher level of serviceability and minimum interruptions to traffic during the life of the concrete resurfacing.

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