Portland Cement Concrete Thin-Bonded Overlay[a]

By Richard J. Wibby[1]

Abstract: An innovative approach to portland cement concrete (P.C.C.) thin-bond overlay is presented. It includes a review of both equipment and methods. A complete presentation of this type of construction is offered, including step-by-step detailing of the construction process. A cost comparison between a P.C.C. thin-bond overlay and an asphalt concrete overlay is also examined.

Introduction

The need for restoration, rehabilitation, and resurfacing (3-R) of existing highways is a pressing national problem. With increasing inflation and declining revenue, the problem of providing the taxpayer with an effective highway program for his tax dollar is the responsibility of both the construction industry and transportation agencies at all levels—federal, state, and local.

The Iowa Department of Transportation and Development, in response to the 3-R problem, was one of the pioneers of portland cement concrete (P.C.C.) thin-bond overlay for rigid pavements (4). In 1954 their first research project in West Burlington, Iowa, proved to be a failure. However, their success in Clayton County during 1977 yielded results that formed the basis for the successful methods being used today.

P.C.C. thin-bond overlays require special preparation of the existing surface to ensure a complete bond between the old concrete surface and the new overlay. The old surface must be completely clean and etched, and a bonding agent applied. When complete bond is achieved, the overlay and base slab act as a monolithic slab. Because of the complete bond between layers, matching of joints as to the type and location is also required. The principal thrust of this paper is to present a step-by-step look at the recent innovations in equipment and methods that allow contractors to meet the requirement of P.C.C. thin-bond overlay work.

Before the construction phase, an evaluation must be made to establish the requirements for an overlay. The evaluation will include consideration of requirements such as: (1) Minimum thickness based on a structural evaluation of the existing pavement in light of projected traffic needs; and (2) the necessity for correcting deficiencies in the existing concrete pavement. The structural design of the overlay is an integral part of the overall pavement rehabilitation framework.

---

[a]1983 ASCE Construction Engineering Scholarship Award.

[1]Student, Dept. of Civ. Engrg., Louisiana Tech. Univ., Ruston, La.

Note.—Discussion open until February 1, 1986. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on November 13, 1984. This paper is part of the *Journal of Construction Engineering and Management*, Vol. 111, No. 3, September, 1985. ©ASCE, ISSN 0733-9364/85/0003-0281/$01.00. Paper No. 19963.

J. Constr. Eng. Manage., 1985, 111(3): 281-292

Method of Construction

Pavement Drainage.—An important part of the design procedure is consideration of proper drainage of the pavement structure. Most problems related to pavement failure are due to water accumulating under the pavement and weakening the subgrade. An effort must be made to eliminate or at least minimize these problems before structural work. A longitudinal shoulder drainage system should be considered and added, if necessary, prior to P.C.C. resurfacing. The purpose of the drains is to quickly remove the water that enters the roadway through joints and cracks in the pavement. Attempts have been made to keep surface water out by sealing the joints using various methods, but seals are not completely effective. Once the drainage system is installed at the edge of the pavement, pavement repair is the next step in the P.C.C. thin-bond overlay process.

Pavement Cracking and Repair.—Rigid pavement distress can be due to two basic causes: (1) Deterioration and deficiency of the pavement itself; or (2) the reduction in structural adequacy of the pavement-base-subgrade structure, or both.

Deterioration might be brought about by alkali-aggregate reaction, scaling resulting from salts, the use of nondurable materials, or freezing and thawing cycles. Some distress in rigid pavement may be caused by improper dowel alinement, warping and curling, or contraction and expansion stresses (5).

A reduction in structural adequacy of the base-subgrade structure may be evidenced by pavement pumping and blowing, corner breaks, faulted joints and other defects. All of these conditions must be corrected prior to the thin-bonded overlay.

Some areas will require full depth pavement repair. Where deterioration is less prevalent, only partial depth repairs are required. This is done by removing deteriorated concrete down to sound concrete (Fig. 1).

Stress Relief Joints.—It is a necessary part of the rehabilitation process to construct stress relief joints in the existing roadway (Fig. 2). The joints must be completed at least 24 hr prior to the resurfacing. These are constructed by making two full-depth saw cuts four in. apart. A diamond saw blade is used to make the cuts. The concrete in the stress relief joints is then removed and the void filled with styrofoam material prior to paving. This joint helps to isolate and relieve slab stresses in the P.C.C.

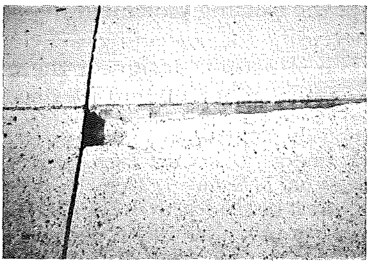

FIG. 1.—Concrete Removed Prior to Patching

J. Constr. Eng. Manage., 1985, 111(3): 281-292

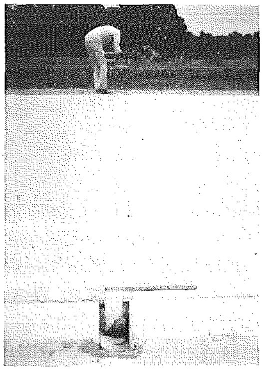

FIG. 2.—*Stress Relief Joint Closure with Time*

rigid pavement. If slab movement causes the relief joint to close completely, it will be necessary to resaw the joint subsequent to resurfacing. The spacing for the relief joints is about 1,000 ft. At the time of sawing, each joint provides immediate stress relief for about 500 ft of pavement on either side (1).

Longitudinal and Transverse Contraction Joints.—The next step is to clean out all existing joints. This is done by sawing with the appropriate width blade. After sawing, a stiff rotary wire brush is used for further cleaning. The location of transverse joints must be marked just prior to overlay. This is necessary because joint construction in the overlay must coincide with the old joints to ensure monolithic slab movement.

A water blaster with a hard hitting nozzle, also, works well for cleaning out longitudinal and transverse contraction joints. A compression seal or cotton backup rope must be used to ensure the joint stays clean during surface preparation.

Surface Preparation.—The successful surface preparation techniques developed by the Iowa Department of Transportation on bridge and highway restoration projects are being used by states all across the nation (4). States have taken Iowa's methods and modified them to produce results satisfactory for the condition of their locales. There have been several types of surface preparation methods utilized including scarification, sand blasting, water blasting, and a centrifugal force machine, which drives metal abrasive pellets against the surface to be cleaned. Still another method involves scrubbing with a detergent, flushing with water, and then etching with muriatic acid. All the preceding methods are adequate in preparing the required surface. However, to achieve maximum efficiency and maximum bonding at the concrete interface a combination must be utilized.

When one fourth of an inch or more of surface removal is required, a Galion RP-30 Road Planer, CMI Roto-Mill, or similar machine works most effectively. Sand blasting works well for oil spots, deep cracks, and paint stripes. Two disadvantages of sand blasting are the resulting requirement of having to remove tons of used sand and the dust problem.

Fig. 3 shows some of the cracking associated with deteriorated rigid

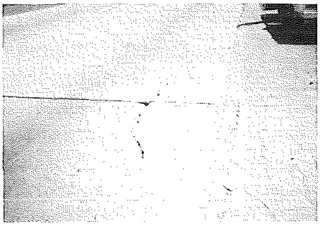

FIG. 3.—Cracks Associated with Rigid Pavement

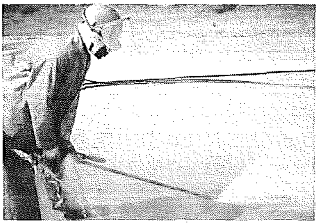

FIG. 4.—Water with Hard Hitting Nozzle at Work

pavements. A water blaster with a hard hitting nozzle (Fig. 4) works faster to remove chips of concrete and debris from cracks than hand chipping. A water blaster with a spray bar is inefficient since the excess water carries contaminates to the lower levels of the pavement. Subsequently the water evaporates letting the contaminates adhere to the pavement.

The latest and largest surface preparation machine to be developed is the BB Blaster (Figs. 5 and 6). This machine operates on the principle of removing the material by hurling millions of tiny steel pellets at the surface each second. These pellets strike the surface at an angle, chipping away a microscopic amount on impact. The deflection angle causes the pellets to rebound at an angle. This rebound action sweeps the chipped material and dust along with the spent abrasive pellets into a collection area in the machine. In the collection area, the pellets and dust are separated. The dust is removed by a vacuum into a portable baghouse that travels along with the machine. The collected baghouse dust is deposited into a hopper. The hopper, when full, can be emptied at desired dumping points. Air that conveys the dust is pulled through finely woven filtration bags and is exhausted clean into the atmosphere.

The steel pellets are returned by the machine to the original deposition point to repeat the cycle. The devices used to hurl the abrasive wheels are similar to flywheels with blades protruding from them at right angles. These wheels collect the steel pellets at the point of entry and throw them mechanically at the surface with speeds of up to 200 mph.

During a surface cutting operation, over one half ton of pellets per minute are recyled through the machine. At very slow speeds the machine will blast a concrete surface leaving highly exposed aggregate. The

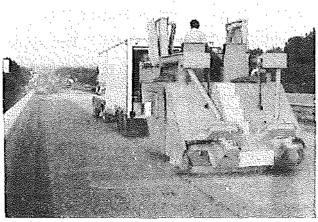

FIG. 5.—BB Blaster

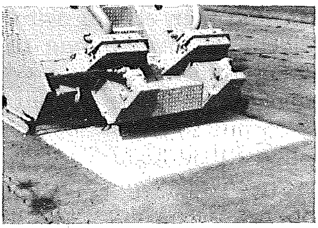

FIG. 6.—BB Blaster

machine is designed to remove only a fraction of an inch of the surface.

The pellets used in the BB Blaster are small enough that the impact does not fracture the aggregate but merely removes the immediate surface with its trapped contaminates. This leaves a clean etched surface with enough profile to be highly adhesive to any coating desired. The BB Blaster can, also, be used for etching a slick surface to provide superior traction.

Power for the machine is supplied by a single 453 N Detroit Diesel engine with power transfer achieved by a hydraulic pump and motors. The machine is 8 ft wide and has an effective cutting width of 7 ft 4 in.

The baghouse is equipped with a 9,000 CFM blower that is powered by a 353 Detroit Diesel. The entire blasting operation is conducted under vacuum conditions so that no dust is introduced into the atmosphere. Since the operation is enviromentally clean, no special breathing apparatus is required. The only safety requirement for people observing or working in the immediate vicinity of the machine is the use of safety glasses or goggles in case an occasional pellet escapes the machine apron.

Mixing.—The concrete is produced by a ready-mix or central mix plant using a standard slip-form mix or a modification of the standard mix. Crushed limestone or soft aggregate is needed to allow for sawing of the joints after the overlay. If a hard aggregate is used it would raise the cost of joint replacement.

Grouting.—One very important part of the success of a P.C.C. thin-bond overlay is the grouting (Fig. 7). The surface must be "clean" and air blasted prior to grouting and placement of P.C.C. The grout may consist of water and cement or a sand, cement, and water mix. The grout is necessary to ensure bonding. The grout may be applied by brushing or spraying onto the dry pavement. Great care must be taken not to allow the grout to be placed too far ahead of the paving operation. If the grout is placed too far ahead and allowed to dry, the grout layer will not adhere or will have a very low bond strength.

Slip-Form Paving.—The concrete is delivered by truck to a concrete spreader or unloaded in front of a slip-form paver (Fig. 8). The slip-form paver (Fig. 9) finishes the concrete. The paver uses electronics to work off a control grade. A texturing machine (Fig. 10) follows the paver placing transverse grooves in the pavement. A "white-pigmented-liquid-membrane" curing compound (Fig. 11), is applied at 1-1/2–2 times the

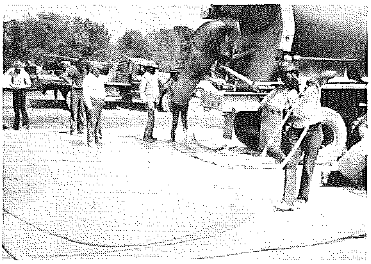

FIG. 7.—Applying Grout

J. Constr. Eng. Manage., 1985, 111(3): 281-292

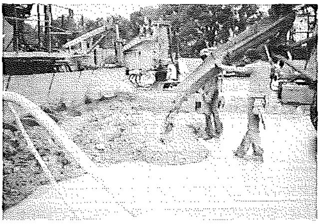

FIG. 8.—Placement of Concrete

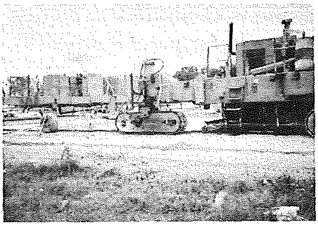

FIG. 9.—Slip-Form Paver

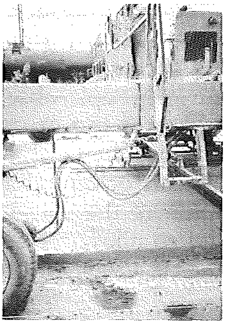

FIG. 10.—Texturing Machine

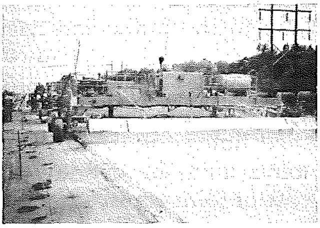

FIG. 11.—White Pigmented Liquid Membrane Curing Compound

normal rate to enhance curing within the P.C.C. thin-bonded overlay.

Sawing and Sealing.—After placement of the overlay, sawing of all transverse contraction joints and relief joints must be done to coincide with the joints underneath (Fig. 12). Longitudinal joints are sawed to the depth of one in. then sealed with the appropriate compression or cold seal.

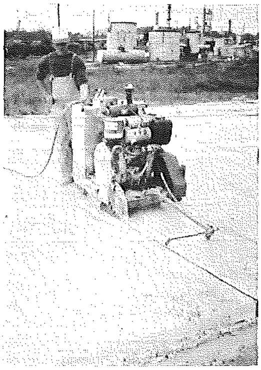

FIG. 12.—Sawing Transverse Joints

Quality Control and Testing

Testing of Bond Strength.—In addition to the normally required tests of the slump, air content, and unit weight measurements, beam, cylinder, and specimen tests are conducted daily to establish strength and freeze-thaw durability. The specimens are cured at the job site for about 24 hr by placing moist burlap over them. Then the specimens are transferred to a laboratory for further curing in a heated vat or in a moist room for a period up to 28 days. After the specimens reach the laboratory they are scheduled for bond and compressive strength tests at the appropriate times, normally 7, 14, and 28 days.

Bond strength is determined by the techniques and equipment originally developed by the Iowa Department of Transportation (4). Many other states have adopted the procedure.

Bond Shear Strengths.—The Portland Cement Association assumes that any bond strength in shear of 200 psi or higher is satisfactory to insure bonding to the existing pavement. Table 1 shows some bond mean shear strengths from past projects using different surface preparation

TABLE 1.—Comparing Bond Strength

Location and type of surface preparation (1)	Bond mean strength (psi) (2)
Clayton County, IA Project (1977)	
On scarified surface	420
On waterblasted surface	559
On sandblasted surface	592
U.S. 61 North of Baton Rouge, La. (1981)	
On centrifugal force surface	756

TABLE 2.—U.S. 61 North of Baton Rouge, 1981

Bond Shear Strengths (28 Days)		
Sample number (1)	Station (2)	Bond strength (lbf/sq in.) (3)
1	94+00	1,013
2	97+00	975
3	100+00	989
4	103+00	1,035
5	106+00	645
6	109+00	707
7	112+00	866
8	115+00	203
9	118+00	945
10	121+00	231
11	124+00	936
12	126+00	541
13	128+00	904
14	130+00	593
Mean strength		756

J. Constr. Eng. Manage., 1985, 111(3): 281-292

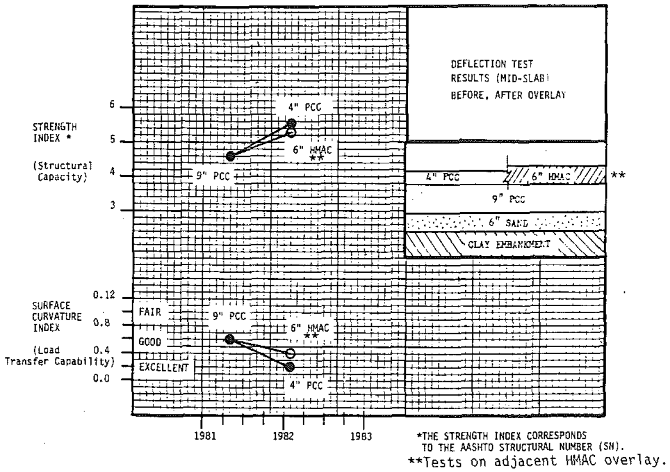

FIG. 13.—Deflection Test Data, U.S. 61 North of Baton Rouge, La., Ref. 4, pp. 22

methods. The mean bond strength was formulated from the data in Tables 2 and 3.

Ride, Skid Resistance, Deflection Evaluation.—An acceptable riding pavement is "a smooth riding surface, but within the economic limits of the area" (5). The concept of the present serviceability index is based on the correlation of measurements of road roughness (roughmeter or profilometer can determine roughness within the pavement) with user opinions to establish the smoothness and rideability of a pavement. This concept is used in this process before and after the P.C.C. thin-bond overlay. The resurfacing improves the skid resistance of the pavement by ensuring a rough texture on the pavement surface that traffic has worn smooth. This in turn produces a safer pavement.

The purpose of a dynamic deflection evaluation is to determine the structural adequacy by direct measurement of the load-deflection response of the pavement structure. A deflection device measures the pavement before and after the P.C.C. overlay. The values from the device are converted to a strength index (ability to carry load) and a surface curvature index, which indicates load transfer capability. A comparison between the original and resurface pavements' strength and load transfer capability can easily be seen from a plot of the test results (Fig. 13).

Cost Analysis

Comparisons.—The actual life of a P.C.C. thin-bonded overlay on a P.C.C. pavement is unknown. The oldest P.C.C. thin-bonded overlay is a bridge deck in the state of Iowa. That bridge deck was resurfaced 15 yr ago. The Iowa Department of Transportation believes that if the bridge deck can perform satisfactorily for 15 yr then P.C.C. thin-bonded overlay on rigid pavement should be equally dependable. Using a life cycle of 15 yr for bonded overlays and 10 yr for asphalt overlays, the

J. Constr. Eng. Manage., 1985, 111(3): 281-292

Iowa Concrete Paving Association (4) developed a cost estimate and the projected economic potential of P.C.C. thin-bonded overlay program for that state's interstate highway system. A 30-yr planning cycle was used for the analysis, which represents a projection of the total length of time that the overlays are to carry traffic on the initial base. The cost model shows a 3″ asphalt overlay to have a total cost of $352,094 per mile and a 2″ P.C.C. thin-bonded overlay to have a total cost of $273,695 per mile.

In Louisiana, the initial cost for a 3″ P.C.C. thin-bonded overlay on U.S. 61, north of Baton Rouge, (3) was $16.77 per sq yd. The cost of asphalt shoulders adds $7 per sq yd, which brings the total cost to rehabilitate the 24 ft roadway and 14 ft of shoulders to $23.77 per sq yd. A comparable 6-in. asphalt overlay would cost $12 per sq yd for the overlay and require an additional $9 per sq yd for the shoulders for a total of $21 per sq yd.

Present State of the Art

The intent of this paper is to present the concept of the innovative P.C.C. thin-bond overlay process. Many who were pessimistic about possible utilization of P.C.C. thin-bonded overlays are now changing their views. Since petroleum products are becoming more expensive, economics will be a critical factor to the highway paving industry.

New pavement cleaning technology along with conventional slip-form methods have permitted thin-bonded concrete resurfacing to become a viable alternative to the bituminous product that has traditionally been used in the restoration, rehabilitation, and resurfacing of P.C.C. pavements.

Ingenuity will play an important role in the development of improved techniques for P.C.C. thin-bond overlays. Improved equipment and innovative construction methods for P.C.C. thin-bond overlay will eventually result in an efficient construction process. It is important to note that significant consideration must be given to two items when working with P.C.C. overlays: (1) Surface preparation; and (2) bonding. The surface must be "clean" to ensure bonding. Presently no one method is totally successful at achieving maximum bonding of the concrete interface. However, each method works well for certain specific situations. It may be necessary in certain situations, that scarification, sand blasting, water blasting, and centrifugal force methods be combined to achieve maximum bond of the overlay to the existing pavement. In Table 3, (Clayton County, Iowa) particular attention must be paid to cores 17 and 25. The bond shear strength for these cores is 91 and 40 psi, respectively. This is an example of two of the six cores that failed because of the application of the P.C.C. overlay over paint. Oil, asphalt, or any contaminates will lower the bond shear strength of a P.C.C. overlay.

The latest machine to be developed is a portable centrifugal force machine. This machine, using a principle applied in steel foundries for years, was developed by Mr. Mike Swain of Houston, Texas (2). The machine has been used on several overlay projects. In Table 1, it can be seen that the bond mean shear strength for this machine is 756–164 psi higher than the next process. The noticeable surface difference achieved by this machine can be seen under a microscope. Magnification of surfaces cleaned

TABLE 3.—Bonded Portland Cement Concrete Overlays LSN-2698-R Clayton County, Iowa

Core number (1)	Station (2)	Overlay thickness, (in.) (3)	Preparation (4)	Grout type (5)	Shear (psi) (6)	Admix (7)	Location (8)	Remarks (9)
Bond Strength in Shear between Original Pavement and Overlay[a]								
1	262+75	2 1/2	Scarified and sandblast	Cement only	505	Mighty	5.9′ RT.	Bad shear plane
2	264+25	4	Sandblast only	Cement only	696	Mighty	8.0′ RT.	Wire mesh
3	267+50	3 3/4	Sandblast only	Cement and sand	811	Mighty	4.0′ RT.	
4	269+00	3 3/8	Sandblast only	Cement and sand	497	Mighty	6.0′ RT.	
5	272+75	4 3/4	Scarified	Cement and sand	449	Mighty	5.6′ RT.	
6	273+25	5 1/8	Scarified	Cement and sand	386	C-4 WR	3.0′ RT.	
7	277+00	4 1/4	Sandblast only	Cement and sand	378	C-4 WR	5.5′ RT.	
8	281+00	4 1/8	Sandblast only	Cement and sand	732	C-4 WR	7.0′ RT.	
9	284+25	2 1/8	Waterblast only	Cement and sand	553	C-4 WR	3.0′ RT.	
10	286+00	2 1/2	Waterblast only	Cement and sand	513	C-4 WR	6.0′ RT.	
11	287+75	2	Waterblast only	Cement and sand	517	Sika	5.0′ RT.	
12	288+50	2 3/8	Sandblast only	Cement and sand	485	Sika	6.0′ RT.	
13	289+75	2 7/8	Sandblast only	Cement and sand	636	Sika	6.0′ RT.	
14	293+00	2 1/4	Sandblast only	Cement and sand	569	Sika	7.6′ RT.	
15	294+00	2 1/2	Scarified and sandblast	Cement and sand	398	Sika	4.0′ RT.	
16	296+00	2 3/8	Scarified	Cement and sand	386	Sika	5.0′ RT.	
17	297+50	1 1/2	Waterblast only	Cement and sand	91	Sika	10.5′ RT.	Over paint
18	297+50	1 5/8	Waterblast only	Cement and sand	819	Sika	Center line	Not round
19	299+90	2	Waterblast only	Cement and sand	621	Sika	10.5′ RT.	Joint corner
20	304+35	2 3/8	Waterblast only	Cement and sand	661	Sika	10.5′ RT.	Joint corner
21	307+00	3	Waterblast only	Cement and sand	537	C-4 WR	4.5′ RT.	
22	310+96	2 1/2	Waterblast only	Cement and sand	839	C-4 WR	10.5′ RT.	Joint corner
23	312+96	3 1/8	Waterblast only	Cement and sand	732	C-4 WR	10.5′ RT.	Joint corner
24	314+50	2 3/8	Waterblast only	Cement and sand	255	C-4 WR	10.5′ RT.	On paint
25	314+50	2 3/8	Waterblast only	Cement and sand	40	C-4 WR	Center line	Paint
26	41+59	3	Sandblast only	Cement and sand	(373)	C-4 WR	10.5′ RT.	Tensile test
27	43+00	2 1/8	Sandblast only	Cement and sand	386	C-4 WR	5.0′ RT.	Old grout 5 hr
28	46+83	2 3/8	Sandblast only	Cement and sand	290	C-4 WR	10.5′ RT.	Possibly paint-not round

J. Constr. Eng. Manage., 1985, 111(3): 281-292

TABLE 3.—*Continued*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
29	47+75	2 1/2–3	Scarified only	Cement and sand	366	C-4 WR	1.5′ RT.	Irregular bond plane
30	49+60	4	Scarified and sandblast	Cement and sand	593	C-4 WR	8.0′ RT.	3-1/2 hr grout
31	51+75	4 1/2	Scarified only	Cement and sand	557	C-4 WR	7.5′ RT.	
32	51+75	4 3/4	Scarified only	Cement and sand	386	C-4 WR	7.0′ LT.	3-3/4 hr grout
33	49+60	4 1/2	Scarified and sandblast	Cement and sand	537	C-4 WR	3.0′ LT.	
34	46+83	2 5/8	Sandblast only	Cement and sand	676	C-4 WR	10.5′ LT.	Joint corner
35	43+00	2 3/4	Sandblast only	Cement and sand	310	C-4 WR	7.5′ LT.	5 hr grout
36	41+59	2 7/8	Sandblast only	Cement and sand	887	C-4 WR	10.5′ LT.	Joint corner
37	314+50	2 5/8	Waterblast only	Cement and sand	1,114	C-4 WR	10.5′ LT.	Paint (bid not shear on bond plane)
38	314+50	2 3/8	Waterblast only	Cement and sand	135	C-4 WR	0.8′ LT.	Paint
39	312+96	1 7/8–2 1/8	Waterblast only	Cement and sand	601	C-4 WR	10.5′ LT.	Corner
40	310+96	2 1/2	Waterblast only	Cement and sand	597	C-4 WR	10.5′ LT.	Corner
41	307+00	3 1/8	Waterblast only	Cement and sand	282	C-4 WR	3.0′ LT.	
42	304+35	2 1/4–2 1/2	Waterblast only	Cement and sand	354	Sika	10.5′ LT.	Corner (sandblast for lane marking)
43	303+60	2 3/8	Waterblast	Cement and sand	406	Sika	5.0′ LT.	
44	299+90	2 1/4	Waterblast	Cement and sand	354	Sika	5.5′ LT.	
45	297+50	2	Waterblast	Cement and sand	No bond	Sika	10.5′ LT.	Paint line
46	297+50	1 5/8	Waterblast	Cement and sand	159	Sika	0.5′ LT.	Paint line
47	295+00	2 1/2	Scarified	Cement and sand	358	Sika	1.0′ LT.	
48	292+00	2 5/8	Sandblast only	Cement and sand	756	Sika	6.0′ LT.	
49	290+00	3 3/8	Sandblast only	Cement and sand	544	Sika	5.5′ LT.	At stop sign
50	285+00	2 5/8	Waterblast only	Cement and sand	107	C-4 WR	7.5′ LT.	
51	278+00	4 1/4	Scarified	Cement and sand	354	C-4 WR	7.0′ LT.	
52	276+00	4 3/8	Sandblast only	Cement and sand	457	C-4 WR	5.0′ LT.	
53	273+00	5 1/4	Scarified	Cement and sand	183	Mighty	5.5′ LT.	
54	268+50	3	Sandblast only	Cement and sand	625	Mighty	7.0′ LT.	
55	264+50	4	Sandblast only	Cement and sand	704	Mighty	6.0′ LT.	Steel mesh

[a]The test of bond strength is a shear test not a tensile test. The test is run by placing two collars around a three-in. diameter core spaced approximately 1/8 in. apart and pulled laterally in opposite directions until a shearing failure occurs. In the preceding tests the bond between the original pavement and new resurfacing was tested.

J. Constr. Eng. Manage., 1985, 111(3): 281-292

by other machines reveals sand in the cavities of the pavement stone that condition leaves less area for adhesion to take place. The surface stays cleaner with the centrifugal force machine because it hurls steel pellets at the surface to be cleaned at a rate of millions per second. These pellets strike the surface at an angle, so that they only chip a microscopic amount on impact. As the spent abrasive pellets rebound at a corresponding deflection angle there is a sweeping of the chipped material and dust back into the machine.

Because bonding is so critical, there is a need for research in the area of grout mix design and method of application. Spraying is the most effective way to apply the grout, although it requires more refined techniques. One possible technique is the use of airless sprayers. Brushing the grout onto the dry pavement is economically inefficient to obtain production. Brushing would require six or more laborers to maintain a productive pace. Two laborers with airless sprayers could obtain distances of a mile or more effortlessly while producing a more unified coverage. The addition of more grout at the edge of the pavement would ensure that dehydration effects due to high temperature of the pavement and ambient air temperature would be reduced.

The dehydration process could also be slowed with the spray application of water on the surface or through use of Napthlene sulfunates or lignon sulfunates.

The application of P.C.C. on top of the grout layer is another important consideration during slip-form paving. Trucks backing up to the front of the slip-form paver will bring dirt and mud on their tires and could result in the possibility of oil leaking onto the pavement. This problem must be addressed. To achieve maximum bond between the rigid pavement and the P.C.C. thin-bond overlay the surface must be clean.

With the federal, state, and local transportation agencies struggling for funding to maintain an effective maintenance program for their highway systems, P.C.C. thin-bond overlay provides a viable alternative. The basic technology of the thin-bond P.C.C. overlay has evolved and appropriate equipment has been developed. With projected long term maintenance costs lower than asphalt, there is a present need to lower the initial cost of the P.C.C. thin-bond overlay process so that total life cycle costs are more favorable. This can only be accomplished by completing more jobs and improving the methods and equipment for the P.C.C. thin-bond overlay process.

Appendix.—References

1. Bergren, J., "Thin Bonded Portland Cement Concrete Resurfacing Highway Focus," Vol. 13, No. 1, U.S. Department of Transportation, Mar., 1981.
2. Better Blast, 1365 Kingwood Drive, Kingwood, Tex. 77339.
3. Temple, W. H., and Rasoulian, M., "Thin Bonded P.C.C. Resurfacing," *Interim Report No. 1*, Louisiana Department of Transportation and Development, Research and Development Section, Baton Rouge, La., June, 1982.
4. *Thin-Bonded P.C. Overlay*, Iowa Department of Transportation Project Open House, Des Moines, Iowa, Sept., 1979.
5. Yoder, E. J., and Witczak, M. W., "Condition Surveys," *Principles of Pavement Design*, John Wiley and Sons, New York, N.Y., 1975, pp. 636–645.