THIN BONDED P.C.C. RESURFACING

FINAL REPORT

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Research Report No. 181

Research Project No. 80-3P(B)

Conducted by
LOUISIANA DEPARTMENT OF TRANSPORTATION
AND DEVELOPMENT
Research and Development Section
In Cooperation with
U. S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION

JULY 1985

ABSTRACT

After the successful experimentation in Iowa with thin-bonded concrete overlays as an alternative to bituminous overlay, the Louisiana DOTD decided to resurface a short section of U.S. 61, north of Baton Rouge, using this technique during April 1981. The resurfacing consisted of 5.8-bag, limestone aggregate concrete mix with a minimum thickness of 3 inches. The average thickness of the overlay was approximately 4 inches due to a change in cross-slope from 1.5 to 2.0 percent.

The existing pavement, constructed in 1959, consisted of 9 inches of concrete over 6 inches of sand on a heavy clay embankment. The section contained dowel bars and a 20-foot joint spacing. The pavement was found to be structurally sound after 21 years of service; however, an improvement in ride quality was needed as the serviceability index had decreased to 2.3.

The old pavement surface was cleaned with a device which blasted the surface with small steel shot instead of blasting sand. The steel shot were propelled by a centrifugal force and reclaimed using a vacuum arrangement which also collected the concrete dust. Less than 1/8 inch of the surface was actually removed during the cleaning operation. A water-cement grout was used as a bonding agent and was sprayed on immediately prior to overlay.

Four months after construction, in August 1981, some disbonding was experienced on slabs adjacent to pressure relief joints which had closed more than anticipated. A high modulus epoxy-resin was used to rejoin the concrete resurfacing at these locations. To date, approximately 16 percent of the exterior slab corners have experienced varying degrees of disbondment. After four years of service, 12 percent of the disbonded corners have cracked.

Slab disbondment at interior slab locations at some transverse joints has occurred but is minimal. To date, approximately 0.3 percent of the total surface area of the overlay has disbonded.

Disbondment is attributed to inadequate grout application procedures, excess air content of the mix and excessive stress buildup at relief joints.

The PCC overlay initially increased the skid resistance of the pavement from 36 to 62 and increased the serviceability index from 2.3 to 4.0. Both parameters have decreased with time but remain within acceptable limits.

Throughout the four-year evaluation period, deflection tests indicate that the majority of the initial increase in structural capacity and load transfer capability has been maintained.

Recommendations are made relative to construction of future thin-bonded PCC overlays.

METRIC CONVERSION FACTORS*

To Convert from	To	Multiply by
	Length	
foot	meter (m)	0.3048
inch	millimeter (mm)	25.4
yard	meter (m)	0.9144
mile (statute)	kilometer (km)	1.609
	Area	
square foot	square meter (m^2)	0.0929
square inch	square centimeter (cm^2)	6.451
square yard	square meter (m^2)	0.8361
	Volume (Capacity)	
cubic foot	cubic meter (m^3)	0.02832
gallon (U.S. liquid)**	cubic meter (m^3)	0.003785
gallon (Can. liquid)**	cubic meter (m^3)	0.004546
ounce (U.S. liquid)	cubic centimeter (cm^3)	29.57
	Mass	
ounce-mass (avdp)	gram (g)	28.35
pound-mass (avdp)	kilogram (kg)	0.4536
ton (metric)	kilogram (kg)	1000
ton (short, 2000 lbs)	kilogram (kg)	907.2
	Mass per Volume	
pound-mass/cubic foot	kilogram/cubic meter (kg/m^3)	16.02
pound-mass/cubic yard	kilogram/cubic meter (kg/m^3)	0.5933
pound-mass/gallon (U.S.)**	kilogram/cubic meter (kg/m^3)	119.8
pound-mass/gallon (Can.)**	kilogram/cubic meter (kg/m^3)	99.78
	Temperature	
deg Celsius (C)	kelvin (K)	$t_K=(t_C+273.15)$
deg Fahrenheit (F)	kelvin (K)	$t_K=(t_F+459.67)/1.8$
deg Fahrenheit (F)	deg Celsius (C)	$t_C=(t_F-32)/1.8$

*The reference source for information on SI units and more exact conversion factors is "Metric Practice Guide" ASTM E 380.

**One U.S. gallon equals 0.8327 Canadian gallon.

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INTRODUCTION

With the near completion of the nation's interstate highway system, emphasis is shifting from construction to restoration, rehabilitation, and resurfacing of our existing highway network. The restoration process of PCC roads and streets has traditionally been accomplished using bituminous materials for resurfacing. Recently, however, petroleum-related paving materials are becoming scarce and therefore more expensive. The slip-form paver along with surface cleaning technology has permitted thin-bonded concrete resurfacing to become a viable alternate for concrete pavement rehabilitation.

After the success with thin-bonded PCC resurfacing by the state of Iowa, the Louisiana DOTD decided to resurface approximately one mile of U.S. 61, north of Baton Rouge, using this technique on an experimental basis.

PURPOSE

The purpose of this research study is to evaluate the constructibility of a thin-bonded PCC resurfacing, and to determine its performance relative to heavy traffic loads and Louisiana environmental conditions.

METHODOLOGY

Project Information

The pcc project selected for resurfacing was a 2-lane section of US 61, north of Baton Rouge, which was to be overlaid upon construction of two new north-bound lanes. The pavement, constructed in 1959, consisted of 9 inches of concrete over 6 inches of sand on a heavy clay embankment. Transverse contraction joint spacing was 20 feet with steel dowel bars spaced on 12-inch centers as the load transfer devices.

Prior to resurfacing, the concrete pavement had carried approximately 120 percent of its design traffic load (3 X 10^6 18-kip axles). Truck traffic on this segment on US 61 is reflective of heavy industrial loads in a variety of categories including chemical, steel, and concrete haul as well as logging and agricultural commodity haul. The 1981 ADT was 7800 with 15 percent trucks. A manual classification count was used to compute an ADL of 750 equivalent axle loads.

Overall, the project was in good condition although the ride was rough, P.S.I. = 2.3. Embankment settlement and erosion of the sand subbase had caused vertical displacement of some of the slabs although the extent of transverse joint faulting was very minor. The primary cause of slab cracking was dowel bar misalignment; however, this condition caused only minor pavement damage. A deflection evaluation using the Dynaflect device confirmed that the concrete pavement was structurally sound after 21 years of service.

Resurfacing Thickness Design

One important consideration in designing a bonded concrete overlay is that the existing concrete pavement must contain slabs which are structurally sound. Broken and shattered concrete must be removed prior to resurfacing. Where D-cracking has undermined the strength of a concrete surface, removal of one-half inch or more of concrete may be required throughout the project by rotomilling, grinding, etc. Concrete pavements in Louisiana do not experience D-cracking because of our extremely hard chert aggregate and mild winters.

An indication of the resurfacing thickness required to prevent fatigue cracking may be derived by subtracting the number of inches of existing sound concrete from the design slab thickness provided by a pavement design guide. For the current overlay project, the Louisiana-AASHTO rigid pavement design guide indicated a required slab thickness of 11 inches on a 20-year design of 8×10^6 18-kip axles. After patching and repair the 9-inch existing pavement would require at least a 2-inch resurfacing. A decision was made to require a 3-inch minimum resurfacing thickness to insure constructibility and because of the absence of a stabilized base course between the pavement and the heavy clay subgrade.

Traffic Control

A positive concrete barrier was employed on each end of the resurfacing project beginning near the median crossover lanes and extending approximately 300 feet. Breakaway plastic barrels were used to separate traffic for the remainder of the project. The plastic barrels proved to be an effective barrier during the two-month lane closure with traffic flowing smoothly and no accidents reported. The success of the plastic barrels was attributed to their high visibility in both day-time and night-time driving conditions and to the breakaway feature when struck by a passing vehicle.

SEQUENCE OF CONSTRUCTION

Pavement Drainage

A longitudinal shoulder drainage system was added prior to the pcc resurfacing. The system consisted of an excavated trench, a perforated 4-inch diameter slotted under-drain pipe, plastic filter cloth, and pea-gravel backfill with a pcc cap at the surface.

Laterals were constructed to facilitate the drainage.

Pavement Cracking and Repair

The existing 20-year-old pavement required only a small amount of repair prior to resurfacing. The estimated quantity for repair was 10 square yards for the 0.8-mile, two-lane section. The predominant cause of broken concrete was dowel bar misalignment. In most instances the concrete, usually fractured from the dowel bars up through the surface, had not become loose under traffic loads.

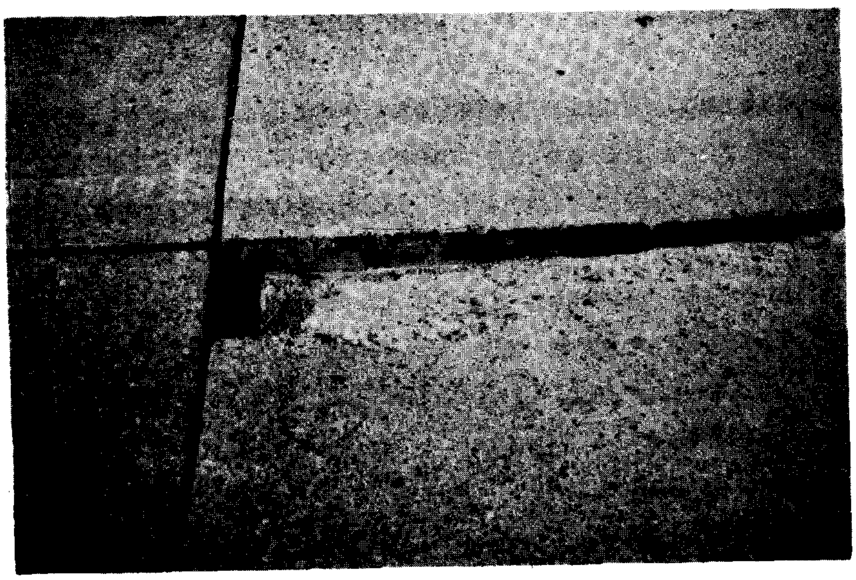
Minor longitudinal cracks extending from the transverse contraction joints and located over dowel bars, may be observed in Figure 1, page 6. This type of cracking is usually found in older pcc pavements in Louisiana which do not contain stabilized base courses, and are usually located in the outside wheel path of the truck lanes. On the US 61 project few of these cracks spanned the 20-foot panels, with a typical crack length being approximately three feet. In most instances the cracks were still very tight with no evidence of faulting; therefore, repair was not considered necessary.

All areas requiring repair were patched with portland cement concrete prior to the surface cleaning operations. Concrete removal as a result of dowel bar misalignment is depicted in Figure 2. It should be noted that in the special provisions for the pcc resurfacing there is an item for only partial depth pavement patching. This is because a full depth patching item was already included in the specifications for the H.M.A.C. resurfacing project of which the pcc resurfacing comprised 0.8 miles.

In several areas, the two 12-foot lanes were separated by a one-half-inch to one-inch longitudinal joint for approximately three to four panels (60 to 80 feet). Pavement repair operations in one of these areas indicated that the lane tie bars had been omitted during construction in these areas. At another location the inside lane was one inch lower than the outside lane.

Longitudinal Cracks Over Dowel Bars
(No patching required)

FIGURE 1



Concrete Removed Prior to Patching

FIGURE 2

Deflection testing indicated that in these areas the concrete slabs were well supported by the sand subbase, therefore no corrective actions were taken prior to resurfacing.

Stress Relief Joints

Three stress relief joints were constructed using two full-depth saw cuts, four inches apart with a 1/8-inch saw blade. One joint was located on each end of the test project and one in the center, for a spacing of approximately 2000 feet between joints. The relief joints were included in the test section to relieve slab stresses and to provide isolation from the rest of the project where transverse contraction joints were not to be cleaned. Another purpose was to determine their constructibility and compatibility with the resurfacing process.

One day after sawing, the relief joints had closed approximately one inch. Figure 3, page 9, depicts the joint closure with time. Twelve slabs on each side of the relief joints experienced movement toward the four-inch joints. Each relief joint provided immediate stress relief for approximately 500 feet of pavement. The relief joints were sealed with a styrofoam type insert upon sawing.

Transverse Contraction Joints

The transverse contraction joint widths ranged from 0.5 to 0.75 inches. The asphalt joint filler which had been used to fill the joints was no longer an effective seal, and most of the joints were impacted with sand and gravel.

The joints were cleaned by making several passes with an abrasive 3/8-inch saw blade. After sawing, a stiff rotary wire brush was used to further clean the faces of the joint. Compressed air was applied to complete the cleaning operation. Water blast equipment was not considered necessary, although it was mentioned in the project specifications in Appendix A, page 35.

Compression seals were installed in the joints as a temporary measure to prevent the metal shot from the surface cleaning device from clogging the joints. A cotton backup rope was first tried but the rope was destroyed by the surface cleaner. After the surface cleaning was completed, the compression seals were removed and replaced with the cotton rope.

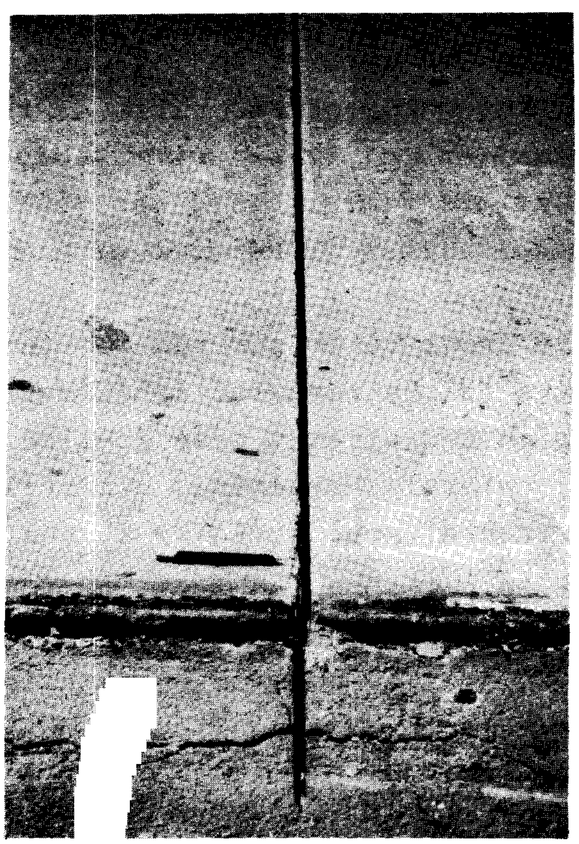
The location of each end of the transverse joints was marked in the asphalt shoulder with a nail and bottle cap. Later after the pcc resurfacing was in place, a chalk line was stretched between the nails to mark the position of the joints for sawing. After cutting the three relief joints, the twelve contraction joints on each side of the relief joints which were displaced had to be remarked for sawing. Figure 4, page 9, depicts the slab movement attributable to stress relief.

Surface Preparation

Throughout the history of bonded concrete overlays, both for bridge deck repair and for roadway resurfacing, the need for a thoroughly cleaned concrete surface has been emphasized. Motor oil dripping from passing vehicles, asphalt concrete, and surface dirt tend to prevent the concrete resurfacing from bonding unless the contaminants are completely removed.

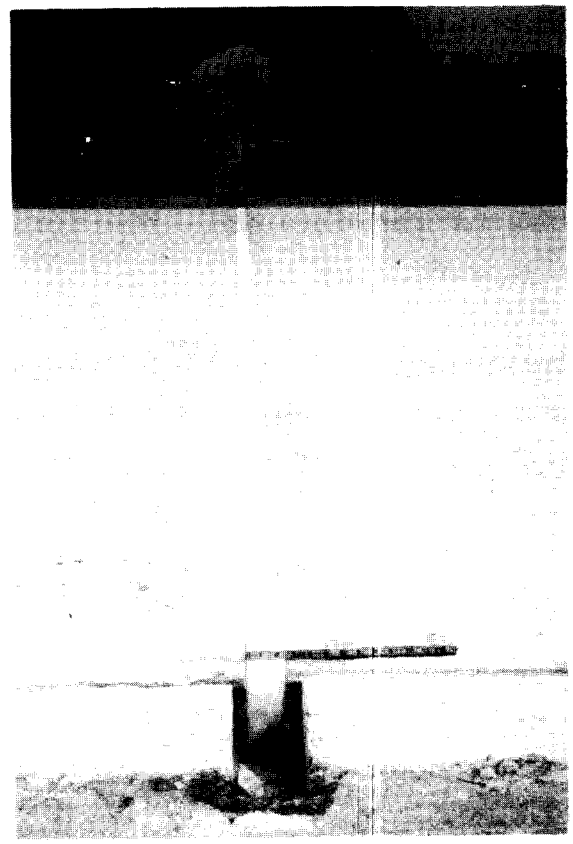
Some of the techniques which have been employed to clean concrete prior to resurfacing include waterblasting, sandblasting, scarification by milling, grinding, and washing with detergent or acid solutions.

The predominant concrete aggregate used in Louisiana is too hard to allow economical scarification by milling. The contractor for this resurfacing elected, instead, to clean the pcc surface by blasting with steel shot. The surface cleaner depicted in Figure 5, page 11,



Relief Joint Closure with Time

FIGURE 3



Slab Movement Due to Stress Relief

FIGURE 4

utilizes centrifugal force to propel the steel shot, with a vacuum arrangement used to catch and bag the concrete dust. Since cleaning was the prime objective in the surface preparation, only approximately 1/8-inch of the pcc surface was removed in each 8-foot wide pass of the cleaner. The newly cleaned surface is depicted in Figure 6, page 11.

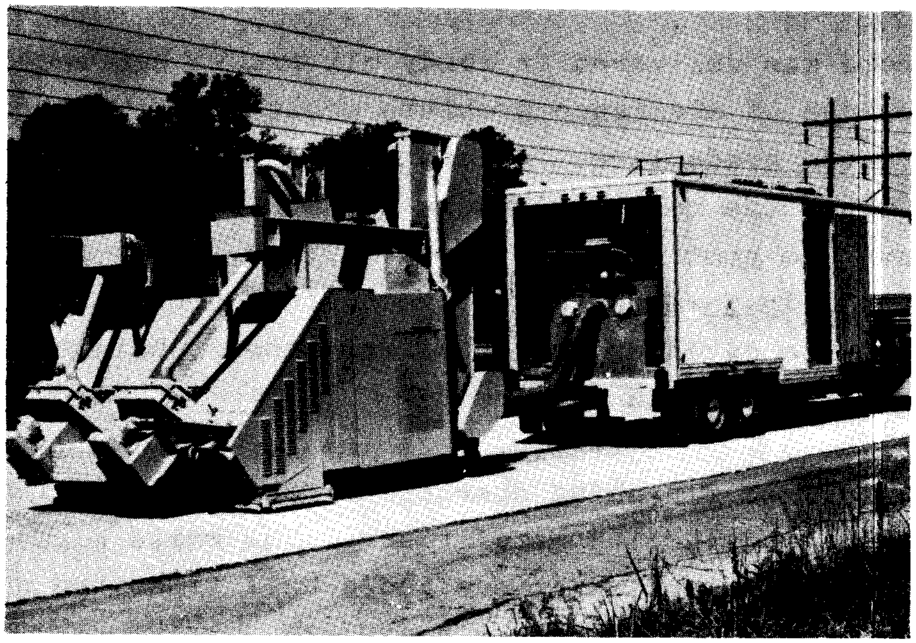
The quality of cleaning was excellent except in areas where asphalt concrete had been smeared on the pcc surface. These locations were primarily along the pavement edge adjacent to the shoulder, and along transverse joints which had been previously filled with an asphalt based compound. A portable grinder was used to remove the asphalt concrete prior to resurfacing.

Paving Operations

The cleaned pcc surface was blasted with compressed air immediately prior to application of the bonding agent--a water/cement grout. The grout was delivered in agitor trucks and sprayed on the dry surface immediately prior to paving. The water/cement ratio of the mixture was approximately 0.62, or 7 gallons of water per bag of cement. The stiff slurry was agitated at all times during use, but it was required that application take place within 90 minutes of mixing.

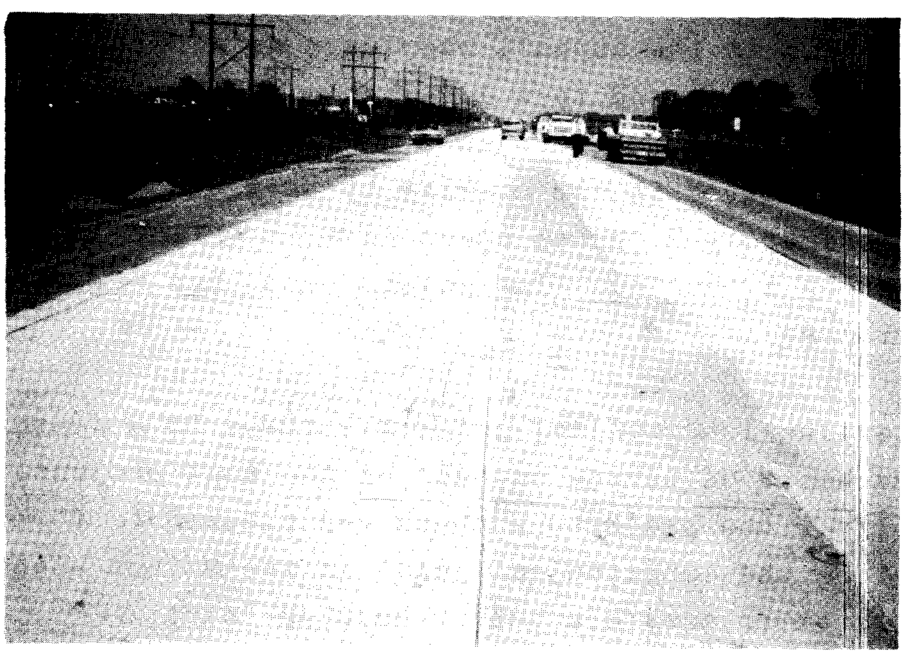
Care was exercised in not allowing the grout to be sprayed too far in advance of the paver. During delays in the resurfacing operation, wet burlap was used to cover grout which had already been applied. The burlap prevented the grout from completely hardening, primarily because of the moderate ambient temperature (approx. 75^{o}F) at the time of paving (April 1st - 5th). It is probable, however, that paving delays of 20-30 minutes in hotter weather would have resulted in hardening of the grout, requiring removal or possibly preventing adequate bond where the grout was partially hardened.

The concrete resurfacing was placed and finished with a slip-form paver with grade wire control to a minimum thickness of 3 inches.



Slab Cleaner

FIGURE 5



Cleaned Concrete Surface

FIGURE 6

The concrete was delivered in ready mix trucks but could not be side-dumped because of clearance problems created by the 5-foot offset of the erected grade line. A load of concrete sand was dumped in the area where the concrete trucks turned in and began backing up to the paver to protect the cleaned surface. When the trucks reached the slip-form paver a polyethylene sheet was placed under the vehicles to catch any motor oil or other substances which might contaminate the cleaned surface.

After the surface finishing operations, the pcc resurfacing was textured transversly with metal tines. The white pigmented curing compound was then applied at one and a half times the normal rate to enhance curing within the thin overlay.

The resurfacing was placed over the transverse contraction joints and the pressure relief joints without using an insert to form the joints. The contraction joints and pressure relief joints were sawed within 24 hours of paving using the nail and bottle cap markers placed in the asphalt shoulders as a reference. The transverse joints were sawed to a 1/2-inch width for the full depth of the resurfacing and sealed with a pourable sealant. The relief joints were created in the overlay by using two parallel saw cuts approximately 2 inches apart (4-inch relief joints had closed approximately 2 inches). The joints were than sealed with neoprene compression seals.

The centerline longitudinal joint was sawed to a depth of 1 inch within 24 hours of paving on half of the test project. For the other half of the project, a crack was allowed to form in the overlay from the longitudinal joint in the 9-inch slab. The sawing method proved to create a better looking joint.

The actual pavement section was 1-1/2 inches thicker at the outside edge of the passing lane as a result of a decision to increase the cross slope from 1.5 percent to 2.0 percent.

The concrete paving mix was Louisiana's standard slip-form mix with the exception of aggregate type and gradation. Crushed limestone was selected as a substitute aggregate to allow sawing of joints through the overlay. The coarse aggregate gradation and paving mix design were as indicated in Table 1.

TABLE 1

COARSE AGGREGATE GRADATION

U.S. Sieve	% Passing (By Weight)
1"	100
3/4"	90-100
3/8"	20-55
No. 4	0-10

CONCRETE PAVING MIX DESIGN

SAND	1192 pounds
LIMESTONE	1920 pounds
CEMENT	545.2 pounds
WATER	31.3 gallons
AIR AGENT	3.0 ounces
AIR CONTENT	5% ± 2%
SET RETARDER	2.9 ounces
SLUMP	1.0 - 2.5

Concrete Consistency

A concrete batch plant was assembled 4 miles south of the project and the concrete was delivered in ready mix trucks. The slump and the air content of the concrete batches were not consistent; however, this did not have any adverse effect on the strength and durability of concrete as indicated by lab tests. On one occasion, the concrete mixing was not performed carefully and approximately 200 linear feet of the resurfacing had to be removed and replaced because an excessive amount of air-entraining agent was introduced into the mix. The quantity of the air-agent introduced was not determined; however, it was sufficient to prevent the resurfacing from bonding to the old pavement. Fourteen-day compressive strength tests indicated low strength in the contaminated section (2000 psi) as compared to the adjacent concrete slabs which showed strength of 4000 psi. Additionally, the unit weight measurements of the cores were reduced by 12 lbs/ft^3 from the average of the 142 lbs/ft^3.

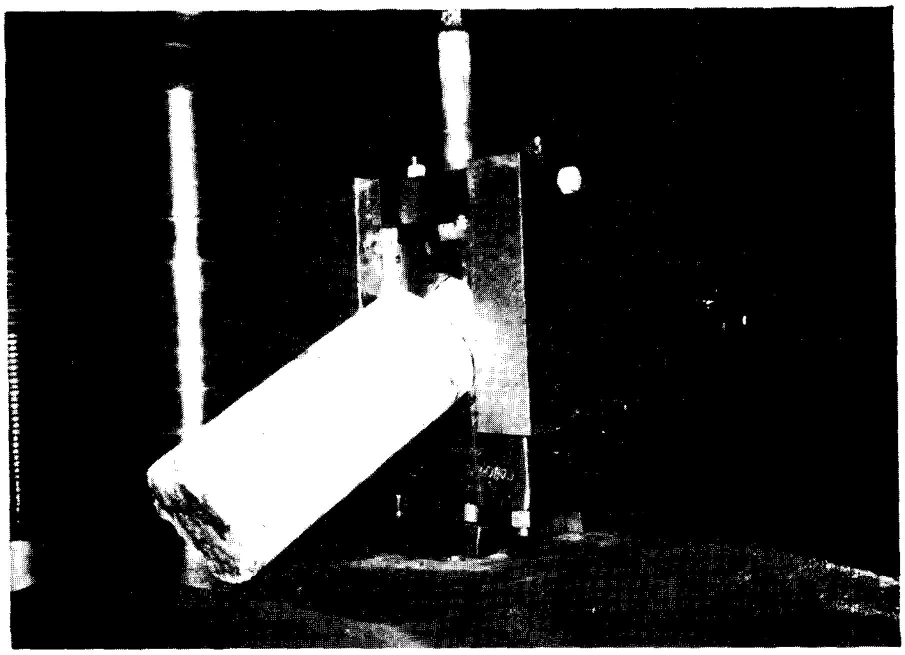
Concrete Testing

The slump, air content and the unit weight measurements of the plastic concrete were taken at several stations throughout the project. In addition to the fresh concrete tests, cylinders and beams, representing each day's pour, were made for strength determination. Specimens were also made for determining the freeze-thaw durability, abrasion resistance and absorption rate of the concrete used for this project. These specimens were initially air-cured at the site for 24 hours and later transferred to the laboratory for further curing in the moisture room. Cores of the pavements were also taken according to the La. DOTD regular acceptance schedule for compressive and bond strength determination.

Bond Strength Determination

The equipment and techniques used for the determination of bond strength were developed by the Iowa Department of Transportation as a result of their experimentation and experience in bonded concrete overlays (1)*.

The equipment consists of a two-part sliding collar which fits over a four-inch diameter core of the resurfaced pavement as shown in Figure 7. The interface plane between the underlying pavement and resurfacing layer is lined up with the junction of the two sliding parts. The collar is then placed into a concrete testing machine, put in tension, and the load required to shear off the resurfacing is measured. By dividing the cross-sectional area of the core into the required force, the bond strength in lbf/in^2 is determined.



Bond Measuring Device

FIGURE 7

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*Underlined numbers in parentheses refer to Bibliography.

DISCUSSION OF RESULTS

Overlay Crack Reflection

After four years of service no reflective cracking has resulted from cracks in the original slab or from areas which were patched prior to resurfacing. Deformed steel tie-bars which were placed in the resurfacing over selected slab cracks and were omitted from others have provided no difference in performance to date. The fact that no cracks have reflected through the thin resurfacing may be in part due to the fact that slabs were well seated and uniformly supported, as indicated by surface deflection tests.

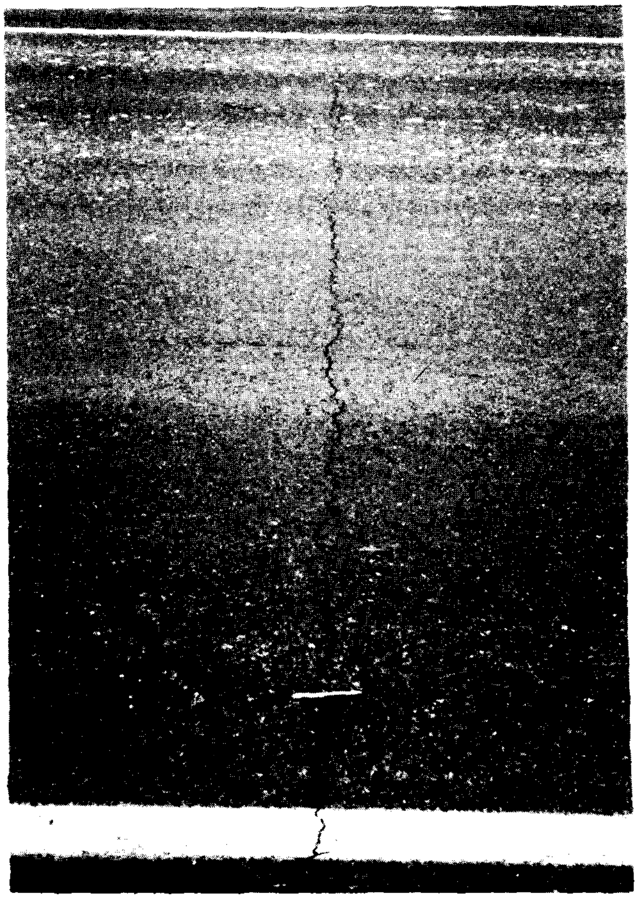
Transverse and Longitudinal Joints

The process of cleaning and subsequent resealing of transverse contraction joints during the pcc overlay process provides a potential performance advantage over bituminous overlays of pcc pavements with contaminated joints. Pcc slabs continue to shift and displace as a result of pressure from locked joints even after an asphalt overlay has been placed. Also, potential for joint/crack reflection is eliminated in the pcc resurfacing. Transverse joints reflected through the adjacent 6-inch bituminous overlay within six months following the overlay, as depicted in Figure 8, page 17. Surface water collecting in this type of crack has been observed to cause stripping of the asphalt in the joint areas leading to fatigue of the overlay.

The longitudinal centerline joints reflected through the resurfacing in areas where it was intentionally not sawed. This produced a crack which was wavey and which typically deviated from a straight line by 2 to 4 inches.

Stress Relief Joints

Although there were few signs of pavement pressure due to joint contamination, it was decided that several pressure relief joints would be constructed to determine the constructibility and compatibility with resurfacing. All three of the 4-inch pressure relief joints experienced approximately 2 inches of closure during the several days between sawing and resurfacing. The three joints were approximately 1-1/2 inches wide after a year of stress relief.



Reflection Cracking in Asphalt Overlay

FIGURE 8

Water/Cement Grout

The water/cement grout was quickly absorbed into the dry, cleaned pcc surface once it was applied. In this sense it was protective of the moisture in the plastic concrete which is necessary for adequate hydration. However, because of delays in paving operations it would probably be unadvisable to apply the grout during the summer months in Louisiana when temperatures are at their maximum. If the grout dries prior to application of the resurfacing, the bond strength may be greatly reduced. This is especially critical at the exterior slab corners where slab temperature differentials cause an upward curling effect which can fail the grout in tension. Additionally, there is a tendency to apply grout less heavily along the outer edges of the pavement when the slurry is applied by one man using a sweeping pattern directed from the center of the roadway. During paving delays, areas with the thinnest applications of grout will tend to dry more quickly resulting in a weaker bond at the outer edges and corners.

Concrete Tests

The unit weight, air content, and the slump of the concrete were checked several times during each day of construction. Concrete specimens were also made for strength and durability determination. The strength of concrete was tested at 7, 28 and 90 days. Abrasion and absorption rates of the concrete were also determined. Tables 3 and 4 in Appendix B, pages 47 and 48, list the results of the strength tests and the fresh concrete test data. The durability and abrasion results are indicated in Table 5 of Appendix B, page 48. As indicated in these tables, the concrete was satisfactory in both strength and durability. The core strengths measured for contract acceptance are listed in Table 6, Appendix B, page 49.

Bond Strength

Initial bond strength tests were run when the first day's paving had aged seven days. The strength values measured were 534, 321 and 461 psi for an average strength of 439 psi. Research experiments in Iowa have indicated that 200 psi is an adequate bond strength and that where such a bond has been obtained it has endured.

The second set of bond strength tests were performed after the resurfacing had aged 28 days. Four-inch diameter cores were taken every 300 feet to represent the 0.8-mile test section. All the cores taken and tested in shear showed bond strengths higher than 200 psi with the exception of one core which had a bond strength of 92 psi. However, another core taken one foot from the low bond strength sample had a strength in excess of 700 psi; therefore, it is possible that the first test was invalid. As indicated in Table 2, the average shear strength was 756 psi at 28 days.

TABLE 2

BOND SHEAR STRENGTHS (28 DAYS)

Sample No.	Station	Bond Strength (lbf/in^2)
1	94+00	1013
2	97+00	975
3	100+00	989
4	103+00	1035
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

Approximately six months after the road was opened to traffic several cracks appeared in the resurfacing adjacent to one of the pressure relief joints. The cracks were closely spaced diagonal cracks near an exterior slab corner in the outside lane. The impact sounding of a three-pound hammer in conjunction with a coring operation indicated that a large portion of a 10-by-24-foot slab on one side of the relief joint had disbonded. The neoprene compression seal which was used to seal the relief joints had been extremely compressed by this time, as the joint now measured 1-1/4 inches. Upon removal of the neoprene seals, it was concluded that placement of the seal only at the upper portion of the relief joint created excessive stresses in the overlay as the joint continued to close. The 10-by-24-foot panel on the other side of this relief joint was bonded for approximately one-half of its surface area. The other two relief joints also experienced some exterior corner disbonding. The neoprene seals were removed from all three relief joints and were replaced with a hot-poured sealant.

The two slabs with the major disbondment were rejoined to the nine-inch slab using a high-modulus epoxy-resin. Four-inch-diameter cores were cut in the corners and center of the slabs through the resurfacing and for four inches into the old pavement. The epoxy-resin was used to fill the core holes, thereby "pinning" the resurfacing back to the original pavement.

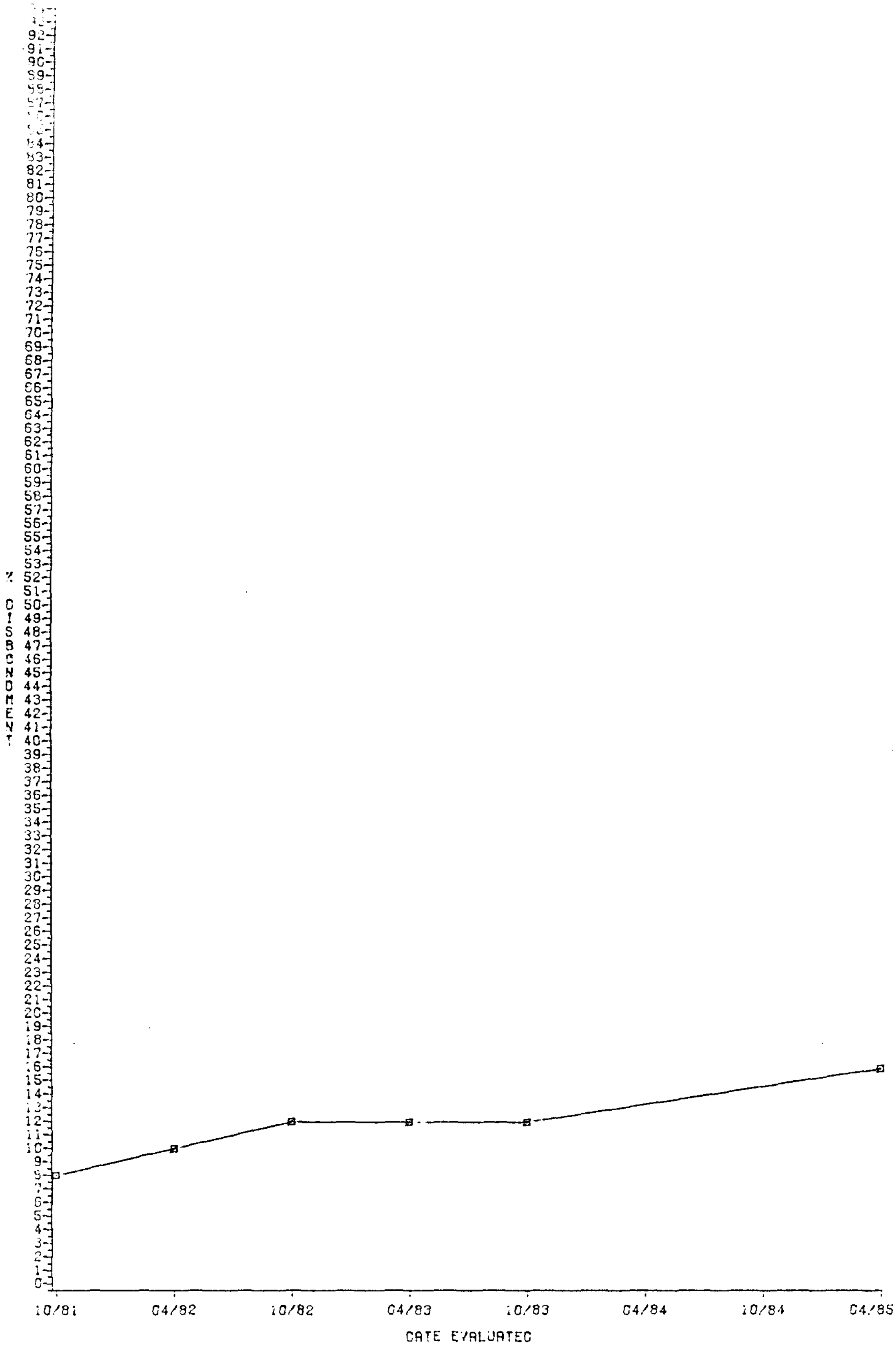
Since construction, the project has been monitored to determine if a loss of bond has occurred between the old pavement and the new overlay. Loss of bond is determined by impact soundings with a three-pound hammer. Approximately six months after construction 8 percent of the exterior slab corners were found to be disbonded. The extent of the separation is typically one to three feet on each side of the corner. The cause of the problem at these slab corners is thought to be attributable to slab curling which places the water/cement grout in tension. The fact that few interior slab corners have disbonded also implies that curling is probably a major factor as the exterior corners have a greater freedom to curl.

Another possible contributor to the corner disbonding is the construction process itself, wherein grout may become too dry during delays in construction. Corner disbonding has been experienced on other thin-bonded pcc overlays such as the Selfridge Air National Guard Base airfield (4). This three-inch resurfacing near Mt. Clemens, Michigan, experienced disbonding on approximately 10 percent of the slab corners on the north runway end but experienced no bond problems on the south runway end. The pavement is reported to be in very good condition after 20 years of active service.

Figure 9 graphically indicates the percentage increase of disbonded exterior corners during the four-year evaluation period. At present 16 percent of exterior slab corners have disbonded, of which 12 percent have cracked on the diagonal from pavement edge to transverse joint.

Areas of disbondment are not restricted to exterior slab corners only. Disbondment also has occurred at isolated locations, at the transverse joints, and occasionally extend well into both lanes of pavement. The majority of disbondment occurring at these interior slab locations are between stations paved during the fourth and fifth days. The 200-foot-long section removed during construction due to excess air content was paved on the fourth paving day. It is felt that areas beyond the 200-foot removal, paved during the fourth day, may have also been partially contaminated by excess air resulting in reduced bond strength. Cores obtained at some of these isolated locations had low compressive strengths, which may be an indication of excessive air content (as in the 200-foot-long section removed during construction) and may have resulted in an inadequate bond strength. To date, a total of approximately 0.3 percent of the surface area of the overlay has disbonded. A disbondment survey of the thin-bonded overlay project is included as Appendix C of this report.

It is felt that the majority of the disbonding problems can be attributed to inadequate bond obtained during construction caused



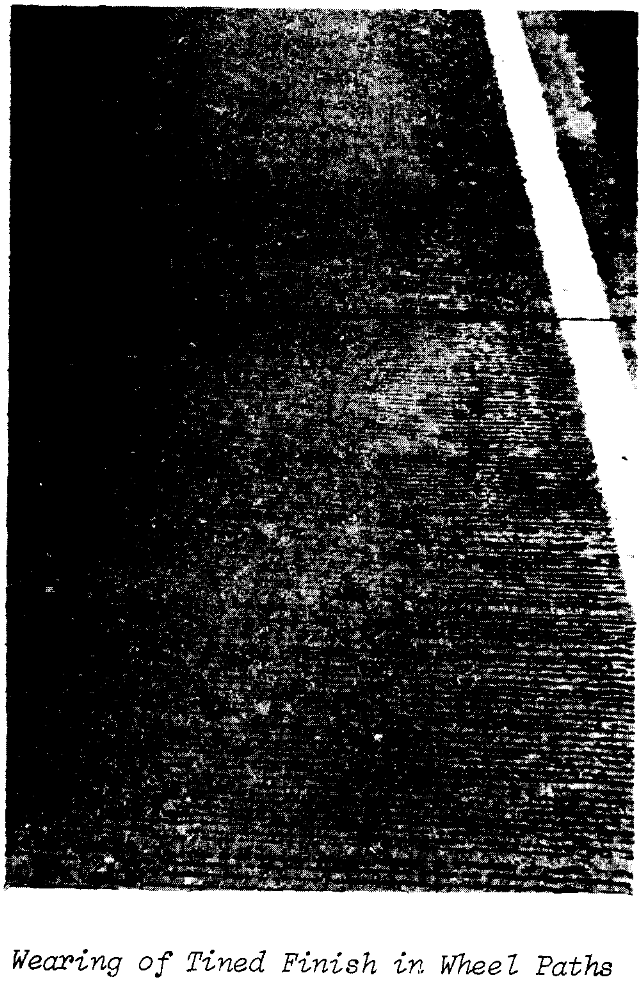
Plot of the Percent of Exterior Slab Corners Disbonded Versus Date Evaluated

FIGURE 9

by either the grout drying out prior to overlay and/or excessive air content in the mix. Disbondment occurring adjacent to the central and southernmost relief joints is attributed to excessive stress resulting from joint closure.

Skid Resistance

The skid number obtained after resurfacing showed a considerable improvement. The skid number of the original pavement surface was 36, which is typical for a 20-year-old concrete pavement, untextured by either tining or grooving. The skid number after construction was increased to 62 by adding the textured concrete surface. Presently the tined surface is visually wearing (Figure 10) in the



Wearing of Tined Finish in Wheel Paths

FIGURE 10

wheel paths and has a skid number of 50. Figure 11 is a graphical presentation of the change in skid resistance of the thin-bonded overlay with time.

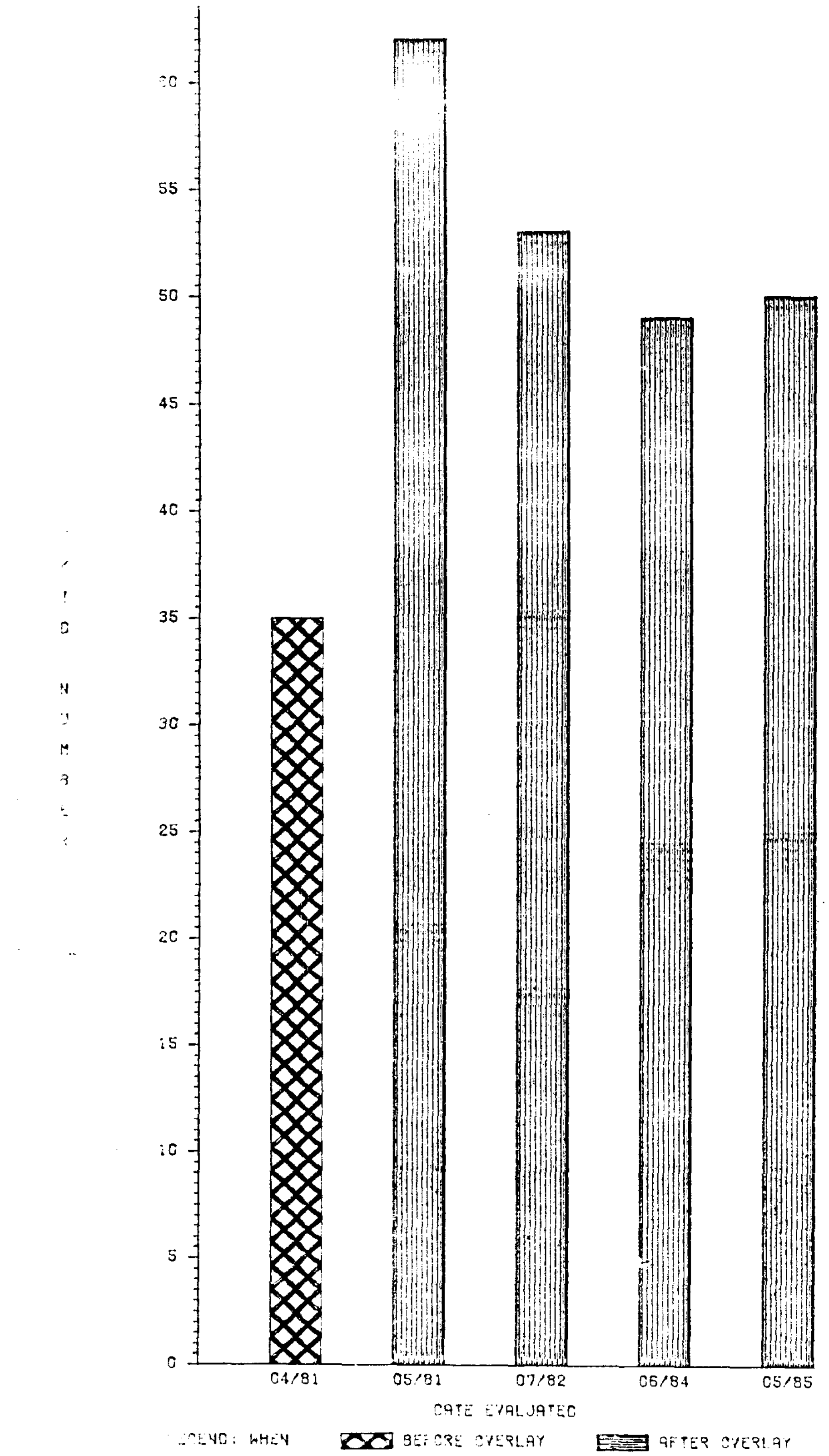
At the time of construction, the adjoining HMAC overlay sections had a skid number of 42. Presently the skid number for the HMAC sections is approximately 38. All skid numbers were obtained in the wheel paths with a locked-wheel trailer at 40 mph.

Ride Quality

The ride quality (S.I. - Serviceability Index) of the thin-bonded pcc resurfacing has been measured periodically with the Mays Ride Meter. A description of the Mays Ride Meter and the S.I. measurement may be found in Appendix D, page 59. As can be seen in Figure 12, both the pcc and HMAC overlays initially increase the ride quality of the pavement from a classification of fair to a classification of very good. To date, the ride quality of both surfaces remain high and are in the good to very good classification.

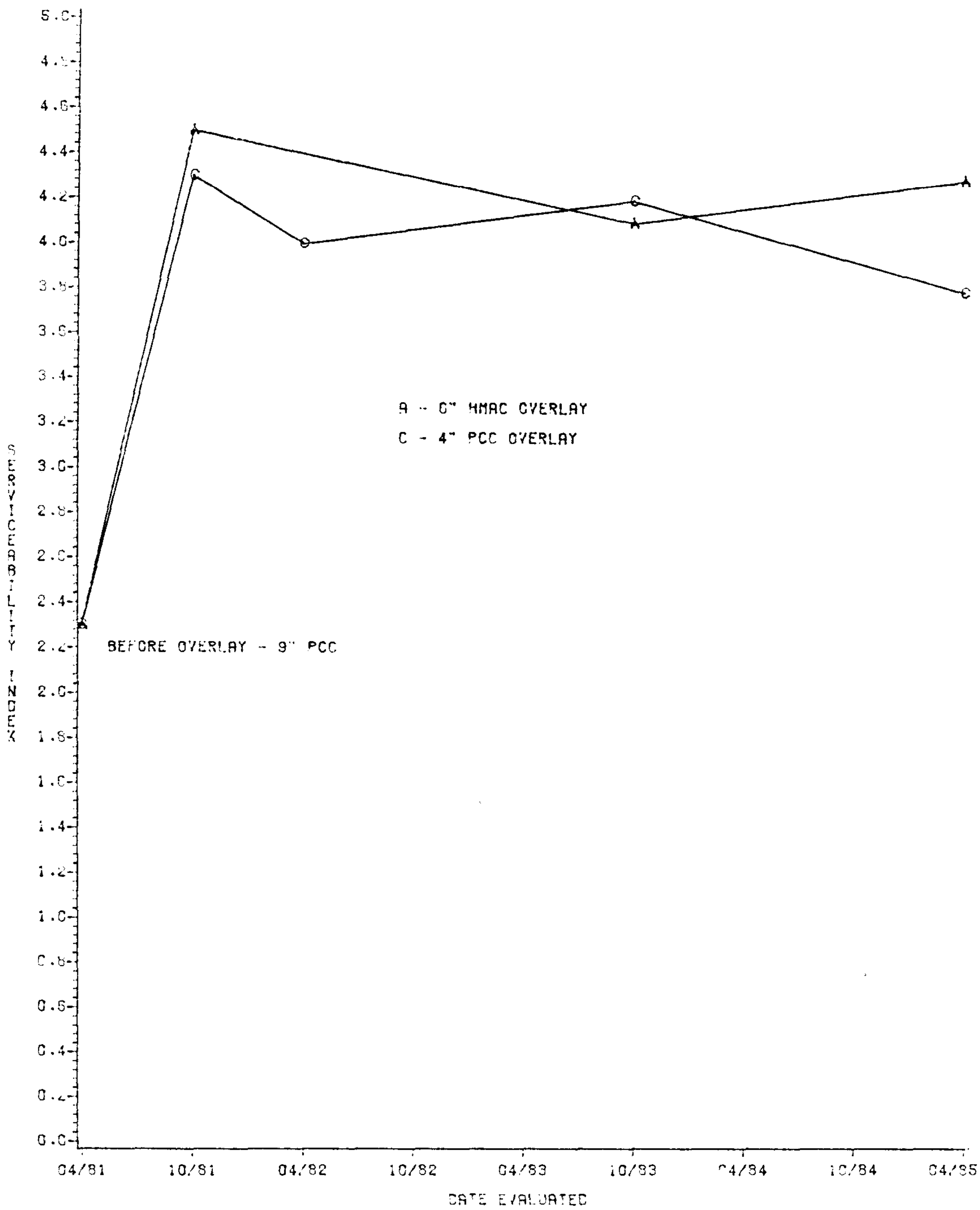
Deflection Evaluation

Surface deflections were measured before and periodically after resurfacing with the Dynaflect device (Appendix D). The deflection values have been converted to a strength index (ability of the total section to carry load) and to the Surface Curvature Index (S.C.I.), which is an indicator of the stiffness or load transfer capability of the upper pavement layers. The strength index is correlatable to the AASHTO strength design parameter SN by methods outlined in a previous Louisiana research publication (6). The deflection data is presented in graphical form in Figure 13. The data indicates that both the thin-bonded pcc and 6-inch HMAC overlays increased the total structural capacity of the original pavement almost equally and that both overlays have experienced a slight decrease in structural capacity with time and loading.



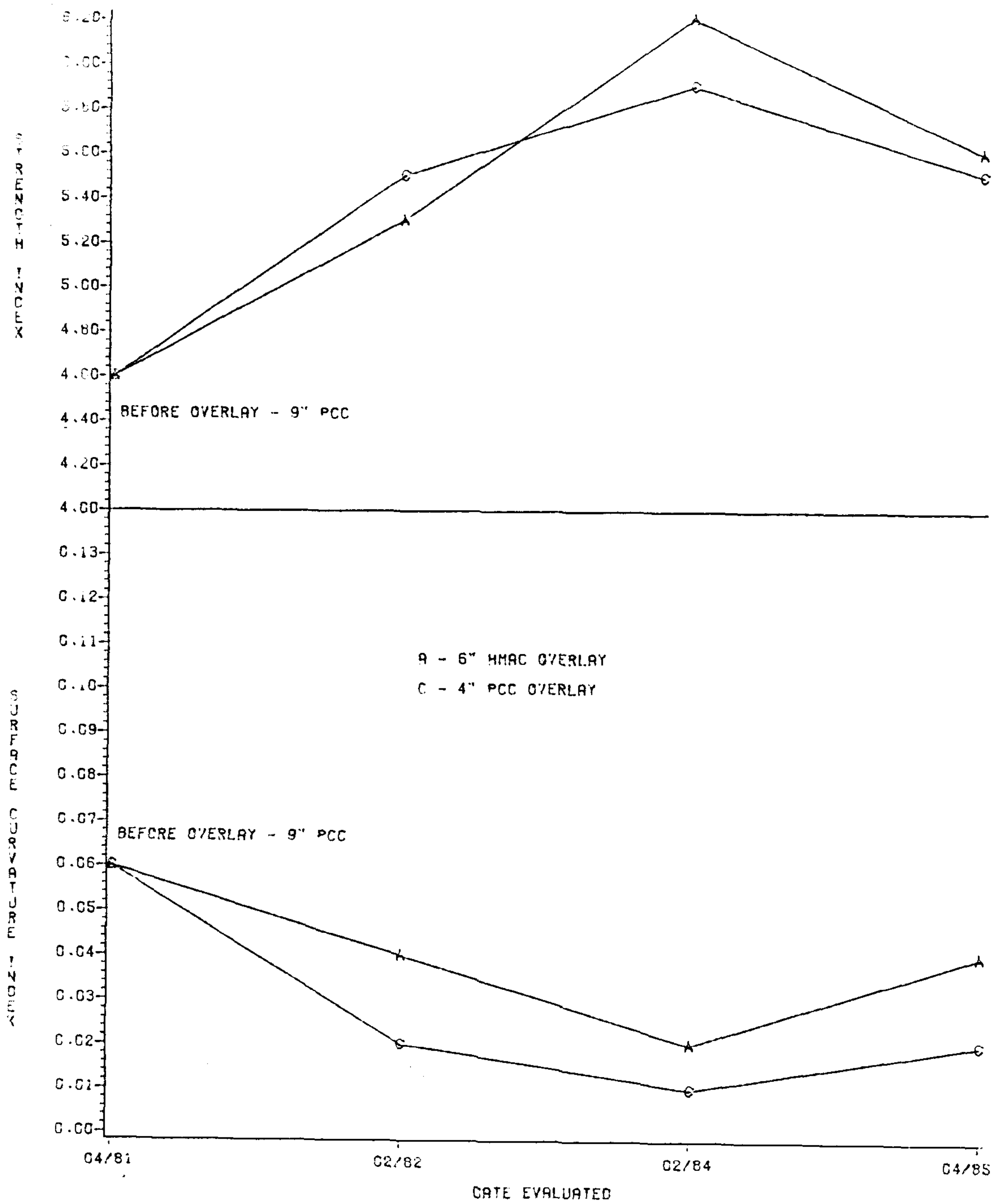
Bar Graph of Skid Number on Date Evaluated

FIGURE 11



Plot of Serviceability Index Versus Date Evaluated

FIGURE 12



Plot of Strength Index and Surface Curvature Index Versus Date Evaluated

FIGURE 13

The stiffness or load transfer capabilities as indicated by the S.C.I. also indicates improvement with both the pcc and HMAC overlays. As expected, the pcc overlay, being a stiffer material, has maintained a lower S.C.I. (greater strength) throughout the evaluation period. As with the strength index, some of the improvement in the S.C.I. has been lost with time and traffic.

Both indices indicate somewhat of a peak strength occurring approximately three years after overlay construction. This strength peak occurring in both the pcc and HMAC overlays is possibly due to seasonally induced strength increases (temperature and moisture conditions) as well as additional compaction by traffic of the HMAC and strength gain with age of the pcc.

Cost of Resurfacing

Computed costs for the pcc resurfacing are based on the experimental 0.8-mile test section and therefore may be greater than would be encountered on a large scale resurfacing project. The actual costs and quantities for the resurfacing are as follows:

Item	Description	Quantity	Cost
724 (1)A	Full Depth Patching	0.41 yd^2	$ 16.40
S1	3-inch min. Concrete Overlay	1,341.23 yd^3	154,241.45
S2	Surface Preparation (cleaning)	10,984.29 yd^2	24,714.65
S6	Stress Relief Joints	3	5,025.00
S7	Pavement Patching (partial depth)	2.33 yd^2	233.00
		Total	$184,230.50

Cost per square yard = $16.77

The cost of adding 10-foot and 4-foot asphaltic concrete shoulders to the overlay increases the total cost per square yard by $7, for a total of approximately $24/yd^2.

A comparable 6-inch asphalt overlay would cost approximately $\$12/yd^2$ for the overlay and $\$9/yd^2$ for the shoulders for a total of $\$21/yd^2$.

CONCLUSIONS

1. The thin-bonded pcc resurfacing appears to be a viable alternative to bituminous overlay in terms of improved ride, skid resistance and added structural capacity.

2. The experimental 0.8-mile section of 4-inch concrete overlay cost approximately $3 more per square yard than the 6-inch asphaltic concrete overlay; however, this cost differential should decrease with an overlay involving larger quantities and as the technique becomes more commonly used.

3. Potential performance advantages of the pcc overlay result from rebuilding, cleaning and resealing of joints, emphasis on patching and repair, the elimination of reflection cracking at transverse joints, and the tined concrete surface which is less susceptible to surface wear-out.

4. Relief joints are a potential source of disbondment if a closure of the joint is experienced. Slab pressure can be relieved during the full-depth repair of blowups and slab fractures, thereby eliminating the need for adding relief joints.

5. High air content (greater than 7 percent) in the overlay concrete mix has the potential of weakening bond to the concrete surface.

6. Exterior slab corners have the greatest potential for disbondment due to slab curl during temperature changes.

RECOMMENDATIONS

1. The action of slab curling places the bonding grout in tension, primarily at the exterior slab corners. Extra care must be taken (a) to assure adequate grout coverage at these corners (approximately 1/4 inch), (b) to prevent the drying of the grout prior to resurfacing, and (c) to provide a grout which is of a creamy consistency.

2. The technique used for surface preparation appears to be adequate; however, the asphalt stains which were concentrated along the pavement edges were difficult to completely remove. Since a completely cleaned surface is necessary for bond, all the asphalt stains must be thoroughly removed.

3. Pressure relief joints are recommended for pavements with a history of blowups; however, care must be taken not to construct or seal the joints in a manner which will transmit the stress to the resurfacing bond. One solution would be to cut the relief joints far enough in advance of the resurfacing operations to allow most of the stresses to dissipate, resaw the joints if necessary, and then resurface the pavement.

4. Thin-bonded pcc resurfacing operations should not be scheduled during the hottest months of the year in Louisiana (i.e., June, July, August). The premature drying of bonding grout will be accelerated when the cleaned pcc surface is extremely hot (95°F).

5. The longitudinal joint between lanes should be saw-cut or induced by using an insert to prevent an irregular reflection crack from forming.

6. Additional research in this area should include thinner resurfacing thickness as well as inclusion of a light water spray applied to the cleaned surface prior to grout application. A moist surface should help prevent the drying of grout when

paving delays occur during hot weather. Application of light water spray without the use of bonding grout is another consideration for future research which might also produce an acceptable bond.

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6. Kinchen, R. W., Temple, W. H., "Asphaltic Concrete Overlays of Rigid and Flexible Pavements," Louisiana Department of Transportation and Development, 1980.

APPENDIX A

SPECIAL PROVISIONS

SPECIAL PROVISIONS
(State Project No. 19-02-38)

ITEMS S-1, S-2, S-6 AND S-7 PORTLAND CEMENT CONCRETE RESURFACING: These items consist of furnishing and constructing a thin (3" minimum thickness) portland cement concrete overlay on existing portland cement concrete pavement, including partial depth pavement patching, preparation of the existing surface and construction of stress relief joints, all in accordance with plan details, Section 601 of the Standard Specifications as amended elsewhere in the project specifications, and the following requirements.

Partial Depth Pavement Patching: The contractor shall remove all unsound concrete by approved methods, and all damaged joint materials shall be removed and replaced with new materials. Prior to placing patching material, all surfaces within the patching area shall be thinly coated with grout. The area shall then be patched with portland cement concrete in accordance with Section 724 of the Standard Specifications.

Surface Preparation: Prior to placing the concrete overlay, all pavement patching shall be completed, and all transverse joints shall be cleaned of all incompressible materials by use of a joint router and water-blast equipment and the joint resealed with backing material as shown on the plans. After completion of patching and joint resealing operations, the contractor shall remove all painted markings, raised pavement markers, loose concrete, dirt, oil, grease and other foreign material from the pavement surface by means of sandblasting, abrading, grinding and/or other approved methods.

Grout Application: Just prior to placement of the concrete overlay, the contractor shall clean the pavement surface to be overlaid by use of air-blast equipment and shall place a bonding grout of portland cement mixed with sufficient water to form a stiff slurry that can be applied to the pavement surface by pressure spray, providing a thin, even coating that does not run or puddle. The water/cement ratio of the grout shall be approximately 0.62, which is 7 gallons of water per bag of cement. The grout shall be agitated at all times during its use, and the cement-to-water contact time of the grout shall not exceed 90 minutes before placement. The pavement surface shall be dry at the time of grout application to allow absorption of the grout. The rate of progress in applying grout shall be limited so that the grout does not become dry before it is covered with new concrete. During delays in the surfacing operations, should the surface of the grout become dry, additonal grout shall be sprayed on the area as directed by the engineer. In areas where the grout becomes thoroughly dried, the grout shall be removed by sandblasting or other approved methods.

Concrete Overlay: If overlay operations are discontinued for any reason, the contractor shall remove all new concrete back to the last transverse joint completed. In no case shall the overlay operation stop between transverse joints.

(a) Coarse Aggregate: Coarse aggregate for the concrete overlay shall be an approved crushed stone conforming to Subsection 1003.03 having the following gradation.

U.S. Sieve	% Passing (By Wt.)
1"	100
3/4"	90-100
3/8"	20-55
No. 4	0-10

(b) Paving Equipment: The concrete overlay shall be placed and finished with an approved slip-form paver in accordance with Subsection 601.18. The contractor shall maintain a uniform rate of concrete placement with a minimum amount of stopping and starting.

(c) Curing: The concrete overlay shall be cured in accordance with Subsection 601.12, except that curing compound shall be applied at 1 1/2 times the specified rate.

(d) Transverse Joints: Transverse joints shall be constructed at existing transverse joint locations in accordance with plan details and Subsection 601.10(c). Joint sawing operations shall be completed within 24 hours after concrete placement and sealed in accordance with Subsection 601.15. Load transfer devices will not be required.

(e) Stress-Relief Joints: Transverse stress relief joints shall be constructed full depth through the concrete overlay and underlying pavement in accordance with plan details. A preformed joint filler conforming to Subsection 601.10(b) shall be placed in the joint, extending from the bottom of the joint to the top of the concrete overlay. The method of construction of the stress-relief joints shall be at the contractor's option, subject to approval of the engineer.

Limitation of Operations: No traffic, including construction vehicles, shall be permitted on the concrete overlay for at least 7 days after placement. At temperatures below 55°F, the engineer may require a longer waiting time. No concrete overlay shall be placed when the air temperature in the shade and away from artificial heat is below 40°F.

All transverse joints, including stress relief joints, shall be sawed and sealed prior to beginning asphaltic concrete overlay operations on adjacent shoulders.

Measurement and Payment: The method of measurement for surface preparation and partial depth pavement patching will be per square yard. Concrete resurfacing will be measured by the cubic yard, based on the theoretical batch at the plant. Stress-relief joints will be measured per each.

Payment will be made at the contract unit prices, which includes furnishing all required materials and performing all operations necessary to complete the portland cement concrete resurfacing. Payment will be made under.

Item S-1, Portlant Cement Concrete Resurfacing (3" Minimum Thickness), per cubic yard.
Item S-2, Surface Preparation for Portland Cement Concrete Resurfacing, per squard yard.
Item S-6, Stress-Relief Joint for Portland Cement Concrete Resurfacing, per each.
Item S-7, Partial Depth Pavement Patching, per square yard.

Item S-3, SHOULDER DRAINAGE SYSTEM: This item consists of furnishing and constructing plastic pipe underdrains in accordance with plan details and the Standard Specifications as amended by project specifications and the following.

The following work shall be performed under this item:

1. Excavation of shoulder underdrain trench.
2. Disposal of all excavated materials.
3. Furnishing and installing plastic filter cloth.
4. Furnishing and installing the perforated underdrain pipe.
5. Furnishing and installing the pea gravel backfill.
6. Furnishing and placing polyethylene film over the backfilled trench (if portland cement concrete is used for base course).
7. Furnishing and constructing shoulder base course and surfacing of either asphaltic concrete or portland cement concrete to replace the removed base course and surfacing during trenching.

Materials:

(a) Perforated Pipe: Pipe shall be either corrugated or noncorrugated; shall be either plastic pipe or plastic tubing; shall conform to AASHTO Designation: M 252 (polyethylene), or ASTM Designation: D 2729 or D 3034 (polyvinyl chloride), or ASTM Designation: D 2751 (acrylonitrile butadiene styrene); and shall have either slot perforations or circular perforations conforming to AASHTO Designation: M 252. Maximum slot perforation length shall be 1 1/4". The stiffness for PVC pipe shall conform to ASTM Designation: D 3034.

(b) Plastic Filter Cloth: Plastic filter cloth shall confrom to Subsection 1017.15 of the Supplemental Specifications elsewhere herein.

(c) Backfill: Pea gravel backfill materials shall be reasonably free of sticks and other foreign matter and shall be graded as indicated on the plans.

(d) Polyethylene Film: Plastic sheeting used to cover the top of the backfilled trench prior to placement of portland cement concrete shall be an approved 6-mil thick polyethylene film.

(e) Asphaltic Concrete: Asphaltic concrete for replacement of removed shoulder base course and surfacing shall conform to Section 501.

(f) Portland Cement Concrete: Portland cement concrete for replacement of removed shoulder base course and surfacing shall be Class A conforming to Section 902 and having a minimum of 7 sacks of cement (94 pounds each) per cubic yard.

Construction Requirements: Installation of filter cloth, pipe, backfill and replacement of shoulder base shall follow immediately behind the trenching operations. At the end of each day's operations, all trenches shall be backfilled. In no case shall trenches be left open at night.

All operations shall be performed in such manner that will not damage the existing roadway pavement not the shoulder surfacing and base course outside the limits of the underdrain trench. Trenching shall be excavated with suitable mechanical trenching equipment that will produce a trench of uniform width and depth. All removed materials considered unacceptable for spreading on slopes shall be disposed of by the contractor outside the highway right-of-way with written permission of the property owner on whose property the materials are placed. The excess and accepted materials from the excavation may be wasted uniformly on embankment slopes or disposed of outside the highway right-of-way at the contractor's option. The contractor shall satisfactorily restore vegetation on grassed areas affected by his operations. Care shall be taken during placement of the filter cloth

(a) Pea Gravel Backfill: The completed trench shall be lined with plastic filter cloth. Adjoining sheets of cloth shall be spliced by lapping at least 18" and satisfactorily securing, or by use of sewn or heat-bonded splices. A sufficient width of cloth shall be placed in the trench to permit the cloth to lap over the top of the trench for the full width of trench.

Underdrain pipe shall be installed in the cloth-lined trench in accordance with Section 703 using approved joining methods. After installation of the pipe, the trench shall be backfilled with the specified pea gravel in a manner that will not cause displacement of the pipe. The backfill shall be uniformly vibrated and compacted with approved equipment to the satisfaction of the engineer. Upon completion of backfill operations, the filter cloth shall be lapped over the full width of the trench and secured by an approved method.

(b) Base Course: Portland cement concrete and asphaltic concrete for replacement of the removed shoulder base course shall be placed in accordance with Section 724. If portland cement concrete is used for the base course, the top of the backfilled trench shall be covered with one layer of polyethylene film. Asphaltic tack coat conforming to Section 503 shall be applied between layers of asphaltic concrete.

Measurement and Payment: Measurement of the shoulder drainage system will be made by the linear foot along the center line of the pipe, complete in place. The accepted quantity of shoulder drainage system will be paid for at the contract unit price under:

Item S-3, Shoulder Drainage System, per linear foot.

ITEMS S-4 AND S-5, OUTLET DRAINAGE SYSTEM: These items consist of furnishing and constructing pipe outfalls for the underdrain system in accordance with plan details and the Standard Specifications as amended by project specifications and the following. The following work shall be performed under these items.

1. Excavation of underdrain outfall trenches.

2. Disposal of excess and unusable excavated materials.
3. Furnishing and installing nonperforated pipe.
4. Backfilling the installed underdrain outfall pipes.
5. Furnishing and constructing shoulder base course and surfacing of either portland cement concrete or asphaltic concrete.
6. Furnishing and constructing headwalls.
7. Restoring of vegetation damaged due to the contractor's operations.

Materials:

(a) Nonperforated Pipe: The pipe shall be either corrugated or noncorrugated plastic pipe or tubing, and shall conform to AASHTO Designation: M 252 (polyethylene), or ASTM Designation: D 2729 or D 3030 (polyvinyl chloride), or ASTM Designation: D 2751 (acrylonitrile butadiene styrene). The stiffness for PVC pipe shall conform to ASTM Desgination: D 3034.

(b) Backfill shall be approved materials from the trench and headwall excavations and/or approved materials for contractor-furnished sources.

(c) Asphaltic Concrete: Asphaltic concrete for replacement of removed shoulder base course and surfacing shall conform to Section 501.

(d) Portland Cement Concrete: Portland cement concrete for replacement of removed shoulder base course and surfacing shall be Class A conforming to Section 902 and having a minimum of 7 sacks of cement (94 pounds each) per cubic yeard. Polyethylene film will not be required over the outfall trenches.

(e) Headwalls: Concrete for headwalls shall be Class A. The mesh hardware cloth called for on the plans shall be heavily galvanized in accordance with ASTM Designation: A 153. Bolts, nuts and washers shall conform to ASTM Designation: A 307 and shall be galvanized in accordance with ASTM Designation: A 153. Welded wire fabric reinforcing shall conform to ASTM Designation: A 185.

Construction Requirements: Trenching, installation of pipe and backfilling shall be performed in accordance with Section 703. Pipe shall have solvent-weld or other approved joints.

At the end of each day's operations, all trenches shall be backfilled. In no case shall trenches be left open at night.

All removed material considered unacceptable for spreading on slopes shall be disposed of by the contractor outside the highway right-of-way with written permission of the property owner on whose property the materials are placed. All excess and accepted materials from the excavations may be wasted on embankment slopes adjacent to the excavations or disposed of outside the highway right-of-way at the contractor's option. The contractor shall satisfactorily restore vegetation on grassed areas affected by his operations.

Portland cement concrete and asphaltic concrete for replacement of the removed shoulder base course shall be placed in accordance with Section 724. Asphaltic tack coat conforming to Section 503 shall be applied between layers of asphaltic concrete.

Headwalls shall be placed in accordance with Section 706.

Measurement and Payment: The completed and accepted outlet drainage system will be paid for at the contract unit price per each, which included trenching, backfilling, pipe, headwalls and the performance of all work necessary to complete the items. Payment will be made under:

Item S-4, Outlet Drainage System (Single Headwall), per each.
Item S-5, Outlet Drainage System (Double Headwall), per each.

APPENDIX B

CONCRETE STRENGTH TESTS

Table 3

COMPRESSIVE AND FLEXURAL STRENGTH
(FIELD MOLDED SPECIMENS) MOIST CURED

STA #	Compressive Strength (PSI)	Flexural Strength (PSI)	Age
133	3884	624	7-Day
133	4723	613	23-Day
133	5462	562	90-Day
128	4196	634	7-Day
128	4924	600	28-Day
128	4992	512	90-Day
120+50	4172	629	7-Day
120+50	4641	675	28-Day
120+50	5630	612	90-Day
110+90	3878		7-Day
110+90	4714	No Test	28-Day
110+90	5509		90-Day
98+97	3260		7-Day
98+97	4379	No Test	28-Day
98+97	4759		90-Day

Table 4

FIELD TESTS ON PLASTIC CONCRETE

Sta #	Slump (in)	Air %	Unit Weight lbs/ft^3	Date Tested	Lin Ft Paved
133+00	3	5.7	144.0	4/1/1981	379
129+50	2 1/4	3.8	146.4	4/2/1981	857
128+00	1 3/4	3.8	148.8	4/2/1981	
127+50	4 3/4	5.0	146.0	4/2/1981	
125+27	3	4.4	147.6	4/2/1981	
120+50	3 1/4	5.3	145.2	4/6/1981	700
118+50	2 1/2	4.5	143.6	4/6/1981	
112+50	2 1/2	5.5	145.2	4/7/1981	420
110+90	3	3.8	146.8	4/7/1981	
98+97	7	3.6	146.8		

Table 5

FREEZE-THAW DURABILITY, ABRASION, AND ABSORPTION DATA

Age Cured	28-Day Absorption (%)	Abrasion (gram/in^2)	Freeze-Thaw DE	Freeze-Thaw Cycles
7-Day	5.2	0.026		
28-Day	4.6	0.013	82	300
90-Day	3.3	0.006		

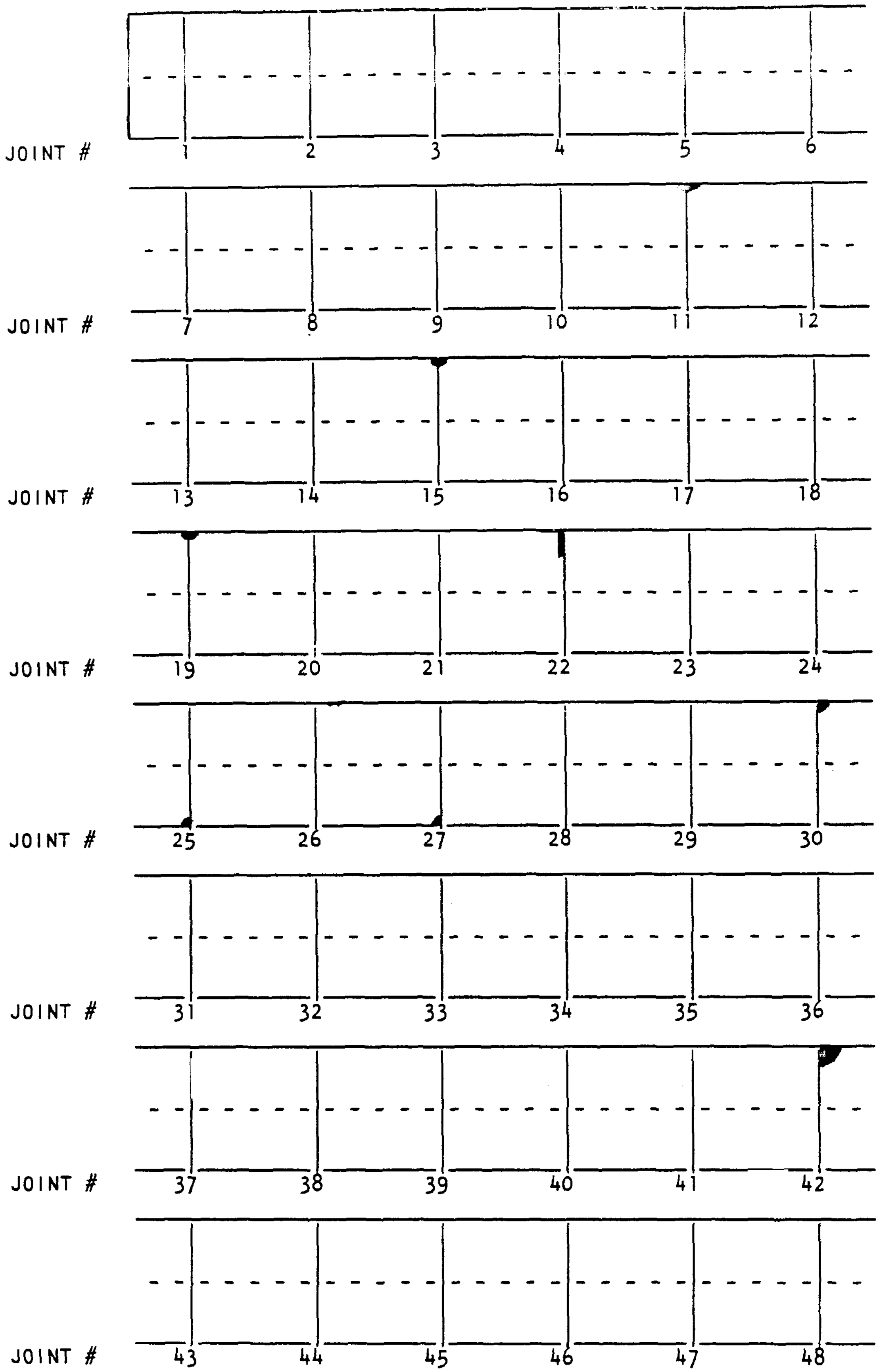
Table 6

COMPRESSIVE STRENGTH AT 28 DAYS
(Contract Acceptance Cores)

Sample No.	Height (In)	Compressive Strength (PSI)
1	4.02	6143
2	3.50	4908
3	3.82	5154
4	3.95	5731
5	4.80	5863
6	3.16	4583
7	3.92	6108
8	4.85	3094
9	3.80	6383
10	3.78	4985
11	4.96	5826
12	3.68	5679
13	4.80	5302
14	4.14	5330
15	5.24	5352

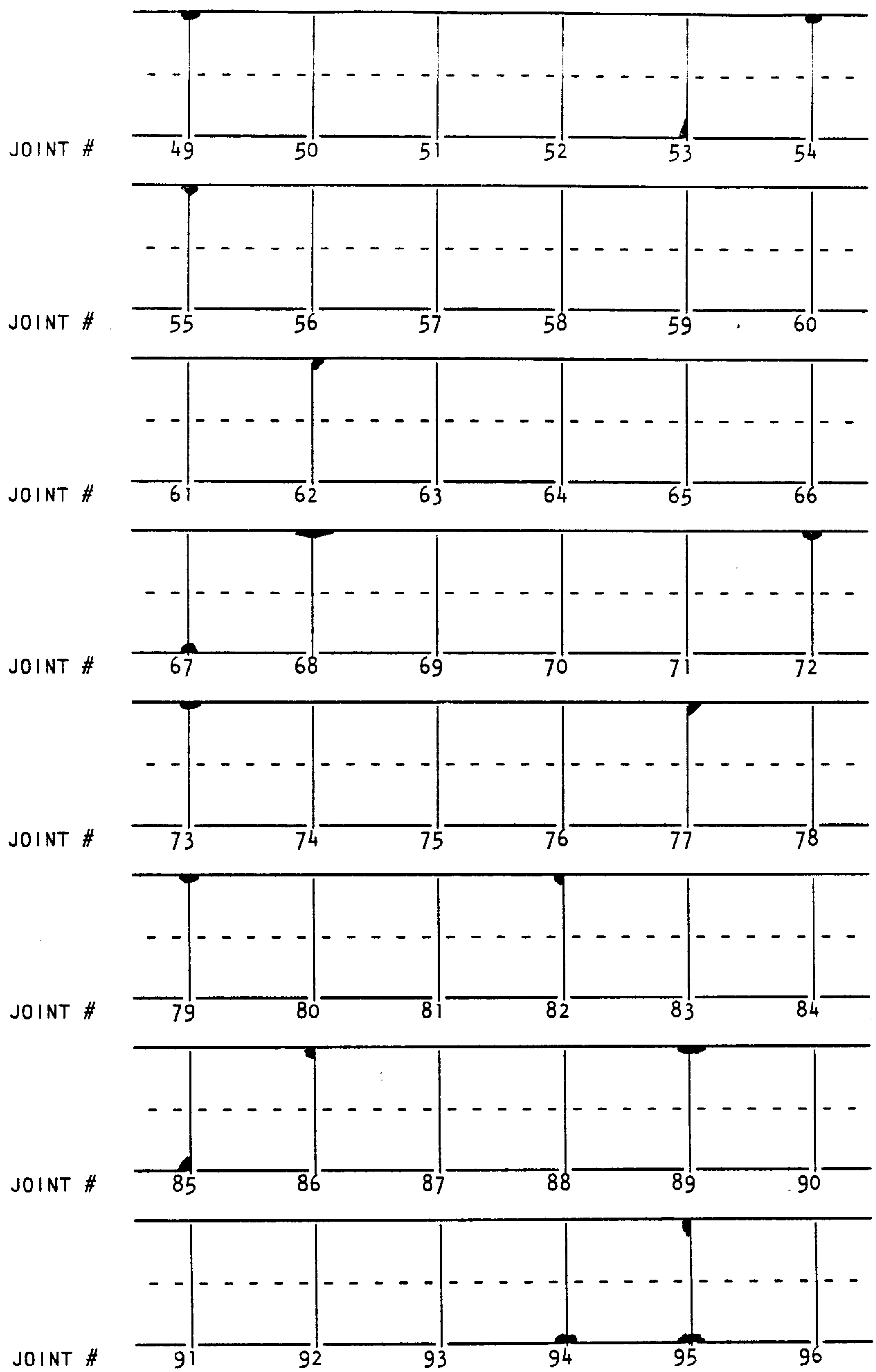
APPENDIX C

DISBONDMENT SURVEY



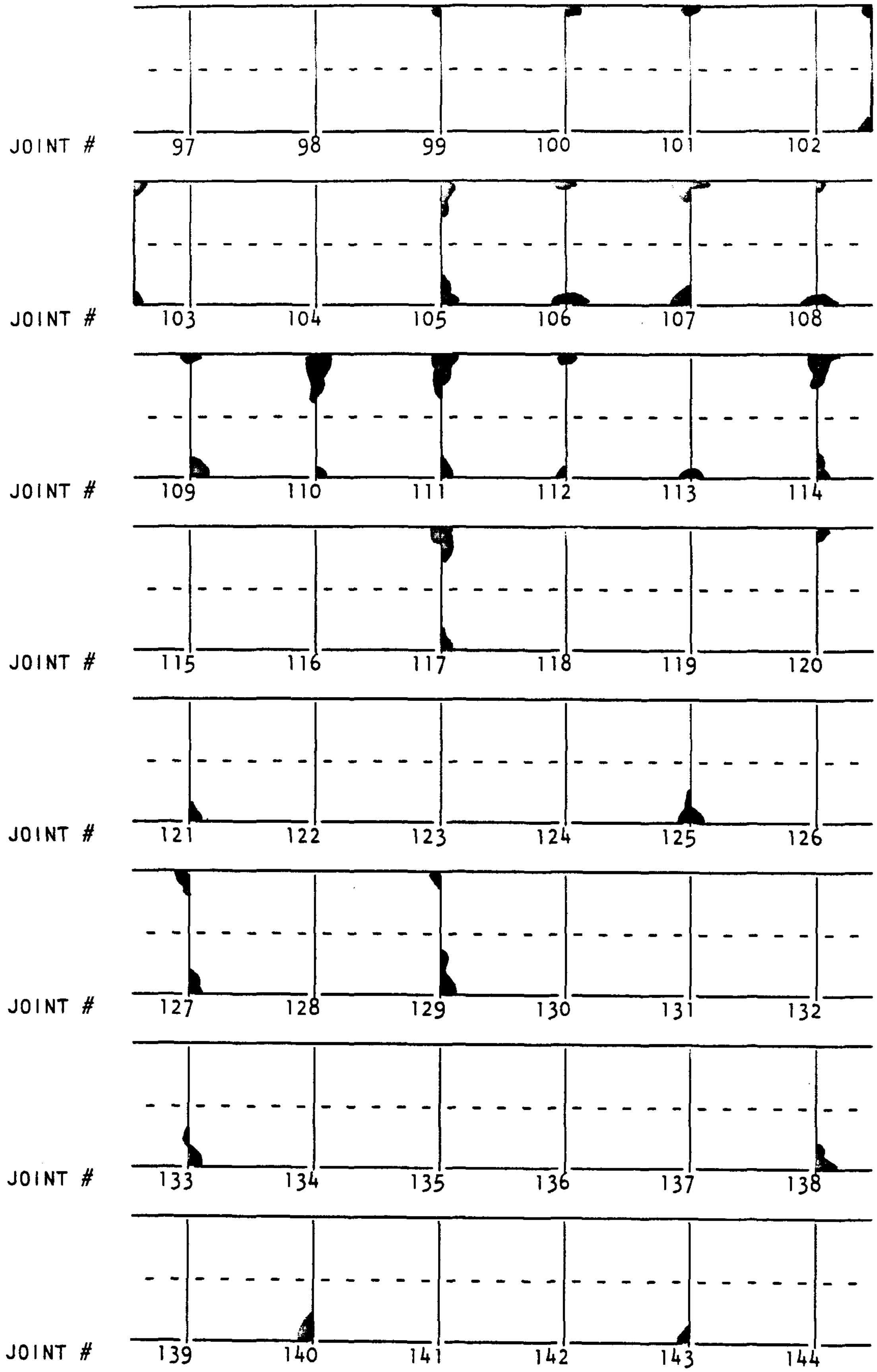
Disbondment Survey

FIGURE 14



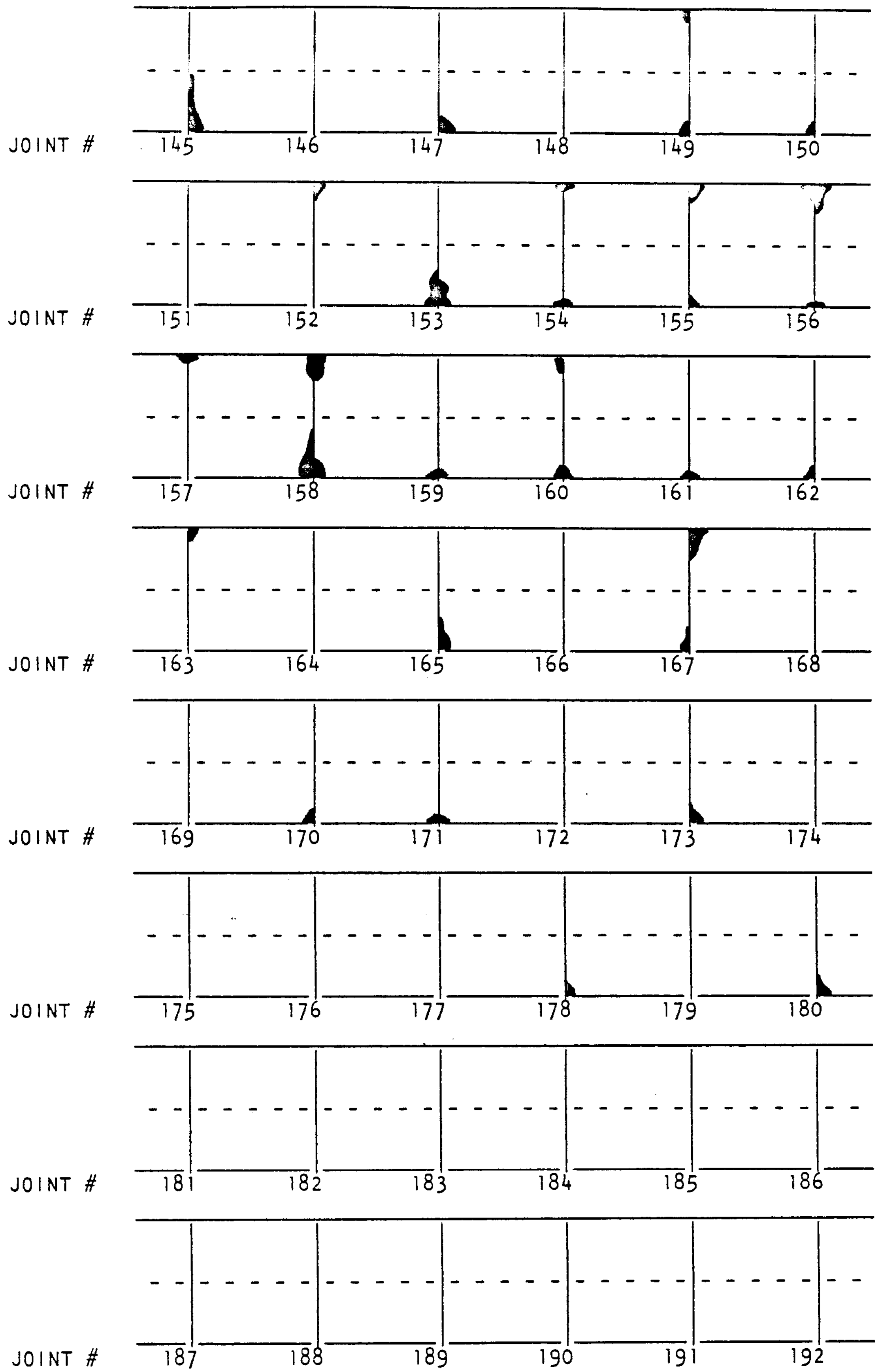
Disbondment Survey

FIGURE 14 (CONT.)



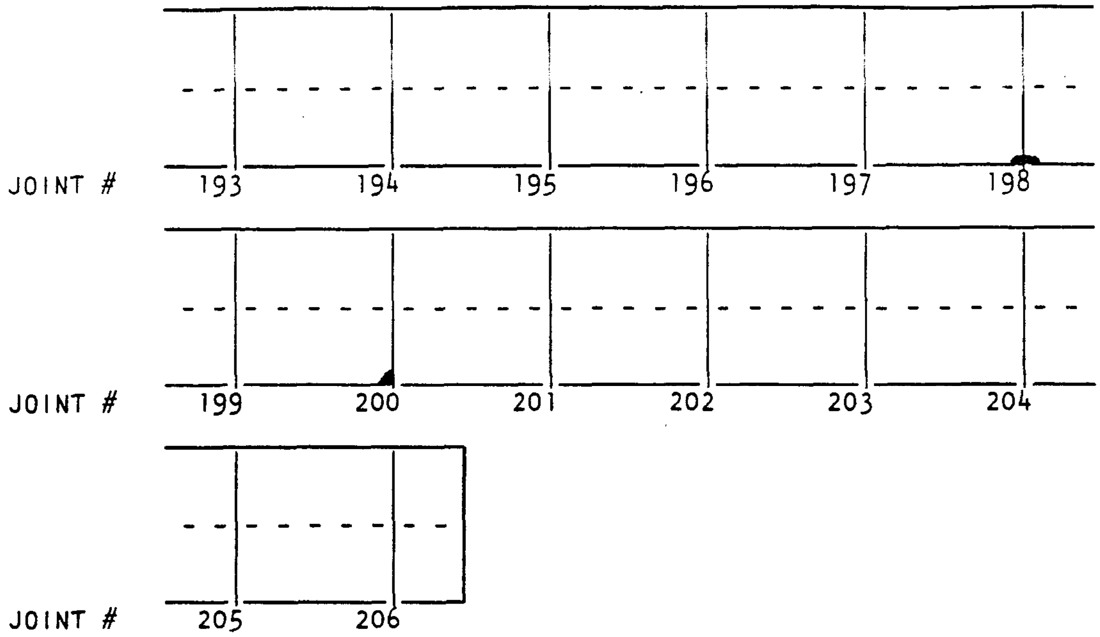
Disbondment Survey

FIGURE 14 (CONT.)



Disbondment Survey

FIGURE 14 (CONT.)



NOTE :
1.) SCALE IS APPROXIMATE
2.) SLABS ARE 24' WIDE AND 20' LONG
3.) AREAS DISBONDED ARE SHADED
4.) JOINT #1 IS AT NORTH END OF PROJECT
5.) JOINT #206 IS AT SOUTH END OF PROJECT
6.) RELIEF JOINT LOCATIONS :
   A. NORTH OF JOINT #1
   B. BETWEEN JOINTS #102 AND #103
   C. SOUTH OF JOINT #206

Disbondment Survey

FIGURE 14 (CONT.)

APPENDIX D

DESCRIPTION OF FUNCTIONAL AND STRUCTURAL EVALUATION EQUIPMENT AND PROCEDURES

FUNCTIONAL EVALUATION OF PAVEMENTS

The Mays Ride Meter (M.R.M.) operates from inside a standard size car and records road roughness as reflected by movement of the vehicle's axle with respect to its chassis. A transmitter attached to the differential collects this movement information and feeds it to a portable recorder located on the front seat. Quantitative and qualitative roughness measurements are presented on a strip chart produced by the recorder. The base speed for the M.R.M. is 50 miles per hour, and correlation curves for each M.R.M. convert test data obtained at other speeds to that at the base speed.

M.R.M. measurements are reported in terms of a Serviceability Index (S.I.). This S.I. has been defined as a "numerical index (ranging from 0.0 to 5.0) of the ability of a pavement in its present condition to serve traffic." Perfectly smooth pavement would have an S.I. of 5.0. Pavement so rough as to be impassable would have an S.I. of 0.0.

More specifically, a numerical-adjective description of S.I. is as follows:

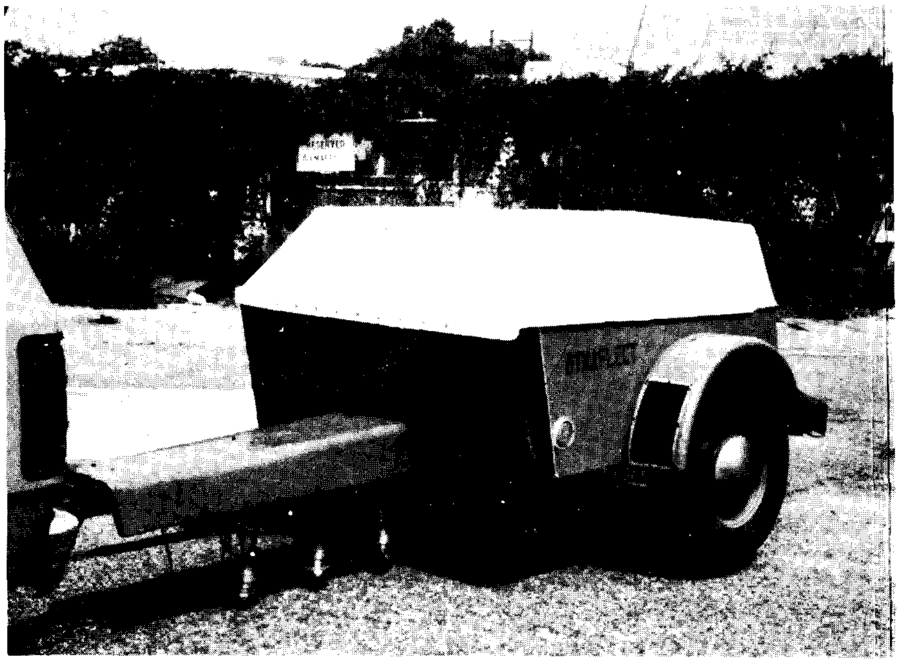
4.1 - 5.0	Very Good
3.1 - 4.0	Good
2.1 - 3.0	Fair
1.1 - 2.0	Poor
0.0 - 1.0	Very Poor

STRUCTURAL EVALUATION OF PAVEMENTS

The Dynamic Deflection Determination System (Dynaflect) is a trailer-mounted device which induces a dynamic load on the pavement and measures the resulting slab deflections by use of geophones (usually five) spaced under the trailer at approximately one-foot (39.5-cm) intervals from the application of the load. The pavement is subjected to a 1,000-pound (454-kg) dynamic load at a frequency of eight cycles per second, which is produced by the counter-rotation of two unbalanced flywheels. The generated cyclic force is transmitted vertically to the pavement through two steel wheels spaced 20 inches (50.8 cm) center-to-center. Any horizontal reactions will cancel each other due to the opposing rotations. The dynamic force varies in sine wave fashion from 500 pounds (227 kg) upward to 500 pounds (227 kg) downward during each rotation. The entire force transmitted to the pavement, however, consists of the weight of the trailer (about 1,600 pounds, 726 kg) and the dynamic force which alternately adds to and subtracts from the static weight. Thus, the dynamic force during each rotation of the flywheels at the proper speed varies from 1,100 to 2,100 pounds (499 to 953 kg). The deflection measurements induced by this system are expressed in terms of milli-inches of deflection (thousandths of an inch).

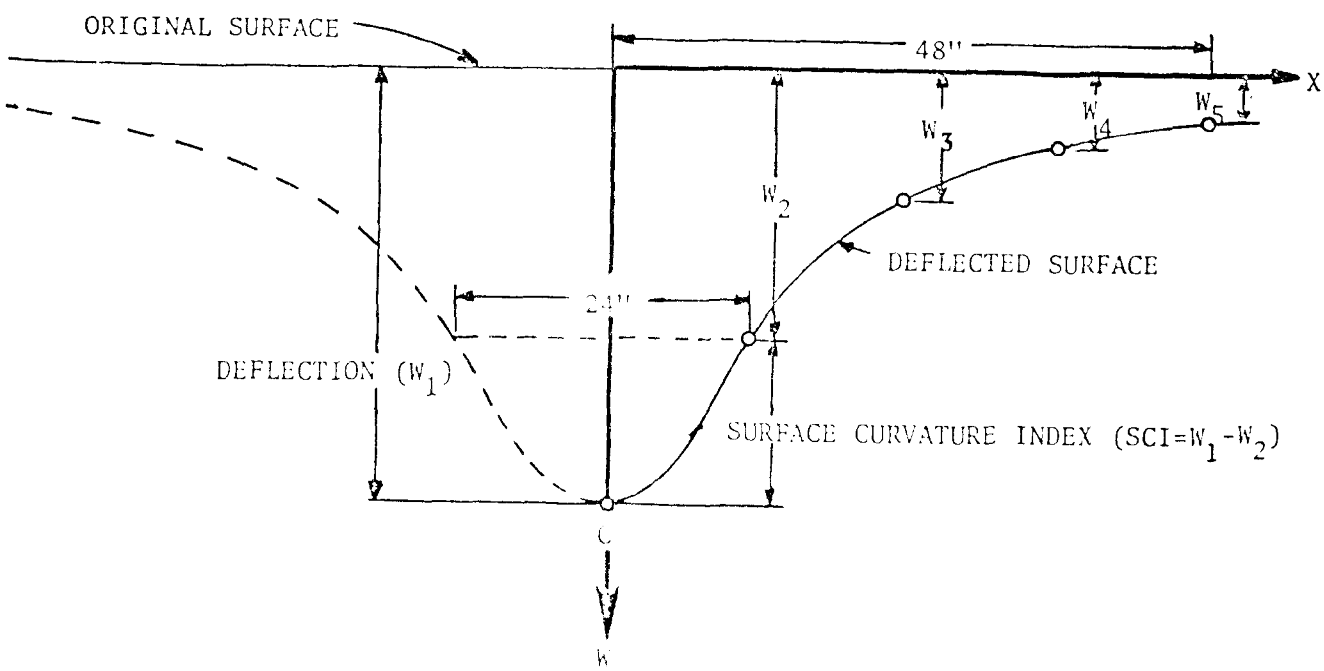
Figure 15 is a photograph of the Department's Dynaflect device. Figure 16 is a representation of the deflection basin which the Dynaflect generates. The Dynaflect actually measures the extent of only one half of the deflection bowl, with the other half assumed to be a mirror image of the measured portion. In Figure 16 the measurement W_1 is the maximum depth of the deflection bowl and occurs near the force wheels. The terms W_2, W_3, W_4, and W_5 are the deflections related by geophones 2 through 5, respectively.

The maximum (first sensor) deflection W_1 provides an indication of the relative strength of the total road section. The Surface Curvature Index, S.C.I. (W_1-W_2), provides an indication of the relative strength of the upper (pavement) layers of the road section. The Base Curvature Index, B.C.I. (W_4-W_5), and the fifth sensor value W_5 provide a measure of the relative strength of the foundation. For all four parameters, W_1, S.C.I., B.C.I., and W_5, lower values indicate greater strength.



Louisiana Department of Transportation and Development
Dynamic Deflection Determination System (Dynaflect)

FIGURE 15



Typical Dynaflect Deflection Bowl

FIGURE 16