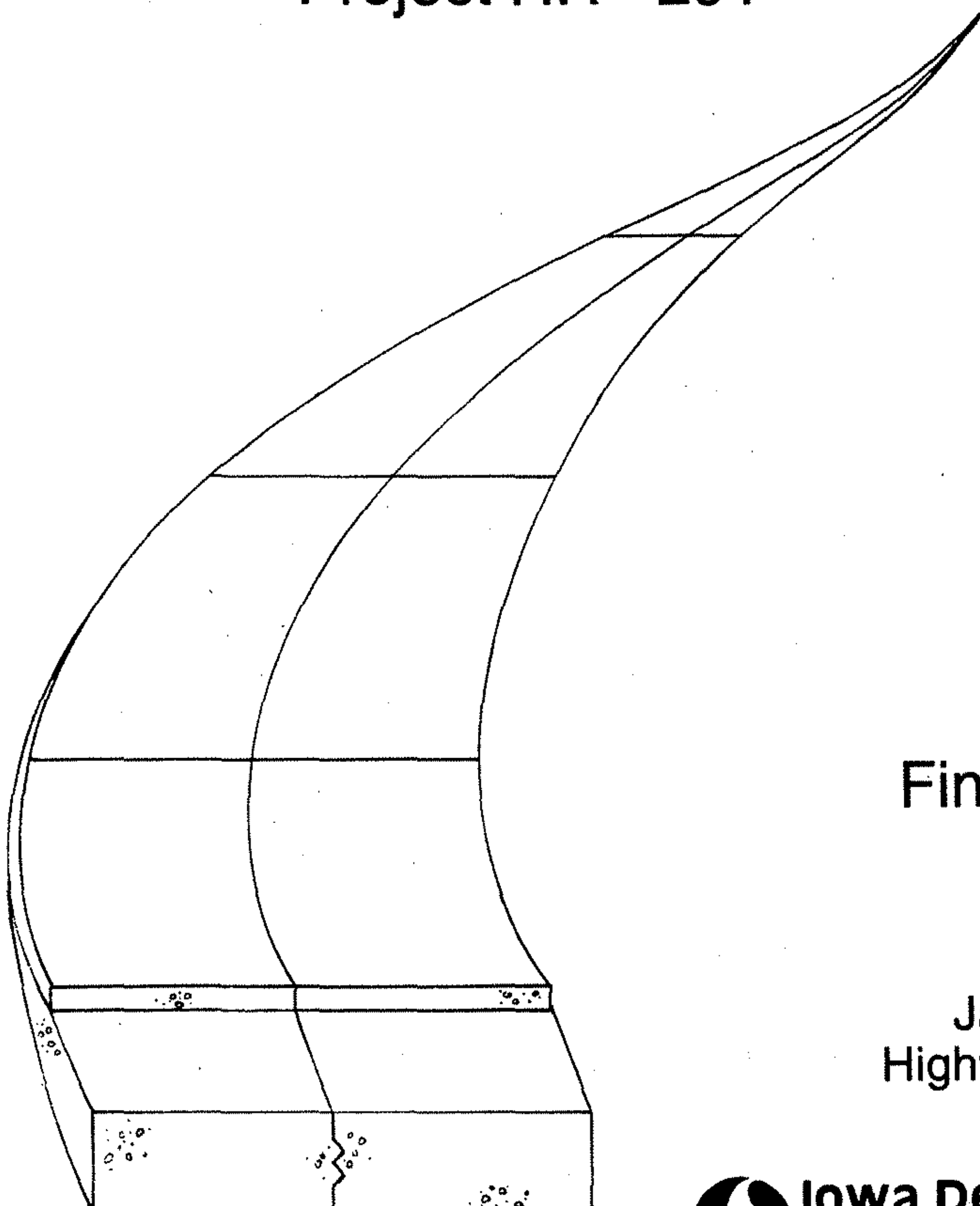
Performance of a Nongrouted Thin Bonded PCC Overlay

Highway Research Advisory Board
Project HR - 291



Final Report

January 1992
Highway Division

Iowa Department of Transportation

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. HR-291	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Performance of a Nongrouted Thin Bonded PCC Overlay		5. REPORT DATE January 1992
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Gary Harris		8. PERFORMING ORGANIZATION REPORT
		10. WORK UNIT NO.
9. PERFORMING ORGANIZATION ADDRESS Iowa Department of Transportation Highway Division 800 Lincoln Way Ames, IA 50010		11. CONTRACT OR GRANT NO.
		13. TYPE OF REPORT AND PERIOD COVERED Final Report June 1985 - December 1991
12. SPONSORING AGENCY NAME AND ADDRESS Iowa Department of Transportation Highway Division 800 Lincoln Way Ames, IA 50010		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Performed in cooperation with the Wapello and Monroe County Secondary Road Departments

16. ABSTRACT

The use of a thin bonded concrete overlay atop an older surface has been widely incorporated for pavement rehabilitation in Iowa since the early 70's. Two test sections were constructed in 1985 on county road T61 on the Monroe-Wapello County line without the use of grout as a bonding agent to determine if adequate bond could be achieved and structural capacity uncompromised.

Both test sections have performed well with one section having higher bond strengths, lower roughness values, higher structural capacity, and less debonding at the joints than the other section. Overall, both ungrouted sections have performed well under substantial truck traffic with minimal surface distress. More attention should be given, however, to rectifying apparent debonding at the joints when no grout is used as a bonding agent.

17. KEY WORDS Grout, Concrete Overlay	18. DISTRIBUTION STATEMENT No restrictions. This publication is available from the Office of Materials-Research, Iowa DOT.

19. SECURITY CLASSIF. (OF THIS REPORT)	20. SECURITY CLASSIF. (OF THIS PAGE)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	21	

Performance of a Nongrouted Thin Bonded PCC Overlay

Final Report
for
Highway Research Advisory Board
Research Project HR-291

Gary Harris
Secondary Road Coordinator
515-239-1382
Materials Office
Highway Division
Iowa Department of Transportation
Ames, Iowa 50010

January 1992

Système International

1 inch = 2.54 centimeters (cm)

1 foot = 0.304 8 meters (m)

1 cubic foot = 0.028 316 8 cubic meters (m^3)

1 cubic yard = 0.764 555 cubic meters (m^3)

1 mile = 1.609 34 kilometers (km)

1 pound (mass) = 0.453 592 kilograms (kg)

1 pound (force) = 4.448 218 Newtons (N)

1 PSI = 6.894 733 kN/m (kPa)

1 gallon = 0.003 785 cubic meters (m^3)

1 square yard = 0.836 127 sq. meters (m^2)

1 pound/cubic foot = 16.018 477 kilograms/cubic meter (kg/m^3)

1 acre = 0.404 686 hectares (ha)

TABLE OF CONTENTS

DISCLAIMER

The contents of this report reflect the views of the author and do not necessarily reflect the official views of the Iowa Department of Transportation. This report does not constitute a standard, specification or regulation.

INTRODUCTION

The Iowa road system has approximately 13,000 miles (20,900 km) of portland cement concrete (pcc) pavements, many of which are reaching the stage where rehabilitation may be required. Age, greater than anticipated traffic, heavier loads and deterioration related to coarse aggregate in the original pavement are some of the reasons that these pavements are nearing the end of their service life.

One method utilized to rehabilitate pcc pavements is the thin bonded pcc overlay. Since the introduction of thin bonded overlays on highway pavements in 1973, progress has been made in reducing the construction costs of this rehabilitation technique. With the advent of the shotblast machine, surface preparation costs have decreased from more than $4.00 per square yard ($4.78/m^2) to most recently $1.50 per square yard ($1.79/m^2). Other construction costs, including placement, grouting and sawing, have also declined. With each project, knowledge and efficiency have improved.

In an effort to further reduce the construction costs, elimination of the grouting operation in the thin bonded overlay techniques has been proposed. The grout has been used in the past to facilitate bond between the new slab and the existing slab, however, the grout with the necessary high water cement ratio may actually impede both the bond strength growth and the ultimate bond strength. The bond strength may also be susceptible to high temperatures and windy conditions which cause the grout to dry prematurely before the concrete is placed. Preliminary work with nongrouted successfully bonded overlays has included field trials on several pavement overlay projects and on new bridges which use precast stay-in-place floor panels with cast-in-place concrete wearing surface. A nongrouted section was an experimental feature on secondary road project RS-7701(9) on the Monroe-Wapello County line constructed in the summer of 1985. Additionally, two Strategic Highway Research Program (SHRP) SPS-7 experimental sections will be built on I-35 in Hamilton County in 1992. These SHRP sections will study the use of grout versus ungrouted, different overlay thicknesses, and various surface preparations. The results should contribute to the knowledge base of bonded overlays.

OBJECTIVE

The objective of HR-291 is to evaluate the performance of two, 250 foot (76.2 m) overlay sections which were placed without using grout to bond the overlay to the original concrete surface. If sufficient bond can be achieved and maintained without using grout, savings in time and money can be realized by eliminating the grouting operation in future overlay work.

EVALUATION

The evaluation consisted of bond shear strengths, pavement deflection data and a visual inspection of both the pavement structure and the individual cores.

PRELIMINARY INVESTIGATION

County road T61 is located on the Monroe-Wapello County line in southeast Iowa. After it was originally paved in 1972, it carried mostly local traffic [380-410 average daily traffic (ADT) with 15% trucks]. In 1984, Cargill Inc. constructed a corn sweetener refinement plant near the north end of the project approximately one-half mile (800 m) south of the junction with IA 137. The anticipated traffic growth due to this new development was expected to be equivalent to one hundred 5-axle, 80,000 pounds (360 kN) semi tractor trailers per day. This was an addition of 175 18-kip (80 kN) ESALs (equivalent single axle loads) per lane per day.

The original road was built in 1972 to the specifications of that time. It was constructed by Central Construction Company of Indianola, Iowa, 22 feet (6.7 m) wide on natural subgrade with an initial PSI rating of 4.2. The road segment was 2.96 miles (4.76 km) long and had 40 foot (12 m) joint spacings with aggregate interlock for load transfer. The existing pavement showed no signs of unusual distress or wear. The maintenance history indicated that very little repair work had been required.

CONSTRUCTION CRITERIA AND PROCEDURES

The 4 inch (10 cm) thin bonded overlay was constructed during the month of June 1985. The existing pavement surface was prepared by shotblasting. Prior to the paving operation, areas seriously distressed were full-depth patched. Where the grout was applied, it was pressure sprayed per Iowa Department of Transportation specifications (Appendix B). Concrete mixed in a central mix batch plant was hauled in dump trucks, which discharged in front of the paver. A Rex Town and County slipform paver finished up to 6400 L.F. (1951 m) per day of the 4 inch (10 cm) thin bonded overlay 22 feet (6.7 m) wide. The new slab was transversely textured and a white pigmented curing compound was applied at 1.5 times the normal application rate. Transverse joints were sawed full depth over the existing transverse joints at 40 ft. (12 m) spacing, and additional 20 ft. (6.1 m) intermediate joints were sawed while the longitudinal joint was sawed T/2, or 2" (5 cm), over the existing centerline joint. After sand and air cleaning, the joints were sealed with a hot pour Sof-Seal per Iowa DOT specification.

PERFORMANCE

As outlined previously, this research project is intended to evaluate the performance of bonded overlays constructed without the use of grout. Cores were taken from the project soon after construction, and tested for shear strength by the Iowa Shear Test (Appendix A). In an effort to evaluate the performance of these sections over time, cores have been taken and tested at regular intervals.

Initial Test Results

The two nongrouted overlay sections are located between stations 419+75 and 422+25 (Section 1) and stations 443+25 and 445+75 (Section 2). Current Iowa DOT specifications for bonded overlays require a minimum bond shear strength of 200 psi (1380 kPa). Bond shear strength tests taken from cores drilled 14 days after construction showed very high bond strengths for the nongrouted test sections; 634 psi (4370 kPa) for Section 1 and 663 psi (4570 kPa) for Section 2. Shear strength tests of grout bonded cores drilled adjacent to the test sections averaged 300 psi (2070 kPa) near Section 1 and 476 psi (3280 kPa) near Section 2.

Bond shear strength tests of pavement cores from the test sections one year after construction showed the grouted areas continued to gain strength while the nongrouted sections remained rather constant. The reason for the appearance of a substantial bond strength gain in the grouted sections is not fully understood. Average values are given in Table I.

The third year evaluation of the research project test sections was undertaken the summer of 1988. Again, cores were drilled in and adjacent to the nongrouted sections for shear strength testing.

Shear Testing

Compared to its first year average value, Section 1's shear strength decreased by more than 200 psi (1380 kPa). In contrast, the average shear strength of cores taken from the grout bonded overlay area adjacent to Section 1 increased by nearly 200 psi (1380 kPa).

Table I
Shear Strengths
Average Values

Location	Average Shear Strength, PSI (kPa) 14 days	1 Year	3 Year	6 Year
Section 1 (Nongrouted)	634 (4370)	623 (4300)	396 (2730)	525 (3620)
Area Adjacent Section 1 (Grouted)	300 (2070)	449 (3100)	627 (4320)	---
Section 2 (Nongrouted)	663 (4570)	654 (4510)	933 (6430)	807 (5560)
Area Adjacent Section 2 (Grouted)	476 (3280)	921 (6350)	1018 (7020)	1022 (7050)

Section 2 and its adjacent grout bonded area continued to show increased bond strengths. Cores were again taken in the summer of 1991. The shear strength for Section 1 improved slightly to 525 psi (3620 kPa) while for Section 2 it decreased to 807 psi (5560 kPa), but still greater than the shear strength of Section 1. When these values are averaged (666 psi or 4590 kPa), it closely parallels the shear strengths for the ungrouted sections after 14 day and 1 year evaluations.

Delamtect Results

The delamtect is an instrument capable of determining delaminations occurring beneath the pavement surface. The instrument sends sound waves through the concrete and measures the time needed for the wave to reflect back to the surface. Delaminations in the concrete will cause the wave to reflect back at the point of delamination. The resulting shorter travel time is then registered as a delaminated area on the instrument printout.

Delamtect tests of the ungrouted test sections indicated some delaminations in Section 1. The debonding is occurring at transverse joints at 40 to 80 foot (12 to 24 m) intervals. The underlying pavement has a joint spacing of 40 feet (12 m). Joints in the overlay are spaced 20 feet (6.1 m) apart, with every other joint being aligned over a joint in the original pavement. The debonding is occurring at those overlay joints lying between the original pavement joints. Differential movement between the overlay and the original pavement is the likely cause of this debonding. The fact that Section 1 is on a fairly steep grade may contribute to some degree of differential movement of the slabs and subsequent debonding. The debonded areas extend approximately 12 inches (.3 m) on each side of a joint and cover the full width of the pavement. This debonding has shown very little increase in the past two years. The Section 2 test results showed no conclusive evidence of any debonding occurring at the joints. If delaminations have appeared in these sections, they are very small at this stage.

Vehicle And Traffic Considerations

Traffic data complete with vehicle classification counts were conducted in 1986 and 1990 to be converted into a number of equivalent 18-kip (80 kN) single axle loads (ESAL) that indicate the magnitude of loads applied to the pavement research sections south of the Cargill plant.

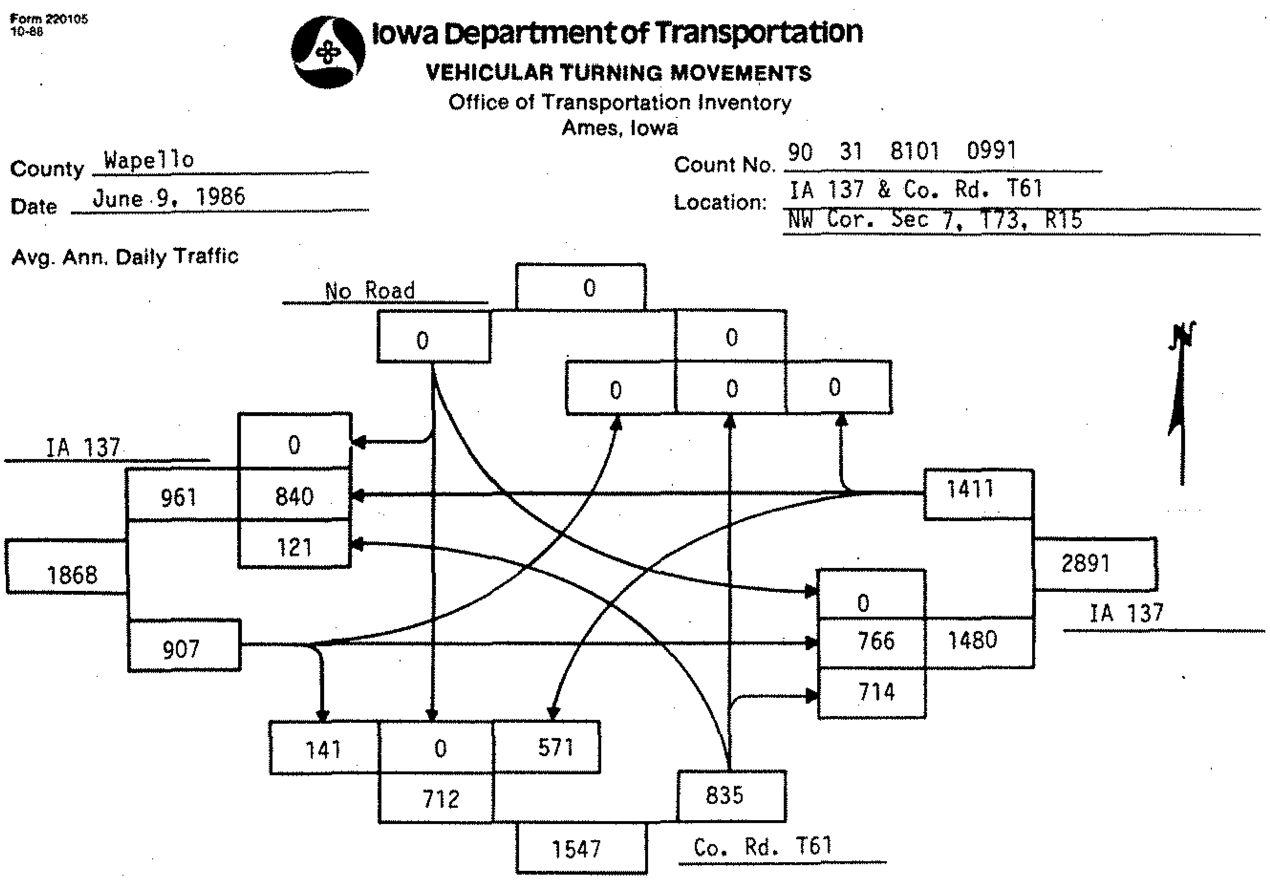


Figure 1

The 1986 analysis showed an ADT of 835 from the south with 19% trucks (Figure 1). By contrast, the 1990 traffic analysis showed an ADT of 1056 with 24% trucks over the test sections (Figure 2). This represents greater than a 1 percent increase per year in overall truck traffic. However, analysis of more detailed data shows a marked increase of 83% in combination trucks over the 1986 figures, giving rise to a substantially larger growth in ESALs (pegged at 7 or 8 percent) than the 1 percent per year overall growth of truck traffic. Based on the data, the total load applied to the bonded overlay is in excess of 400,000 ESALs to date.

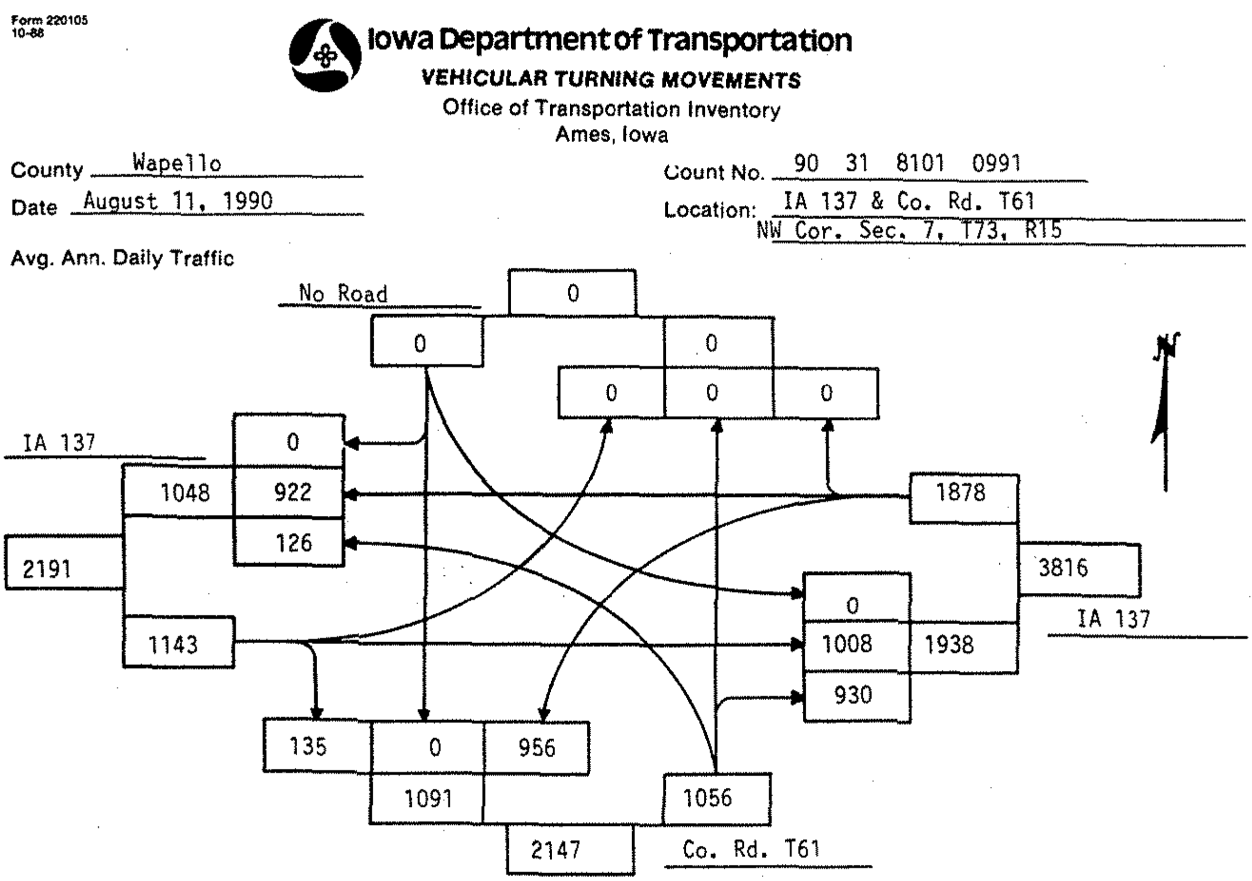


Figure 2

Road Rater

Road Rater testing has been conducted annually on the entire project. The Road Rater is a dynamic deflection measuring device used to determine the structural adequacy of pavements. It can be seen from Figure 3 that the annual structural ratings for the northbound lane are higher than those for the southbound lane, except for an anomalous value in 1990. Figure 4 bears a similar relationship for structural ratings over joint locations with an anomalous rating for 1991. The contrasting difference in values between the north and south lanes over the entire project can be attributed essentially to a variation in traffic loadings. A majority of the trucks entering the Cargill corn sweetener refinement plant turn south off of Highway 137 onto T61 and then unload their grain. It follows that the southbound lane has experienced a greater share of 18-kip (80 kN) ESAL loadings, and thus has consistently lower structural ratings than the northbound lane.

It is interesting to note a converse relationship in structural ratings among the ungrouted test sections 1 and 2 with that aforementioned (Figure 5). These sections lie south of the Cargill plant on which the loaded grain traffic must travel north to unload. Thus, the northbound lane has experienced the larger degree of 18 kip (80 kN) ESAL loadings, and consequently has a lower structural rating than the southbound lane. Again, there is an anomaly in the results for Section 2 in 1989. This may be explained by the fact that annual testing is performed in the outside wheeltrack during the months of April and May when the roadway exhibits the greatest instability, and depending upon the amount of moisture in the soil at the time of freezing, the structural rating can vary from one year to the next.

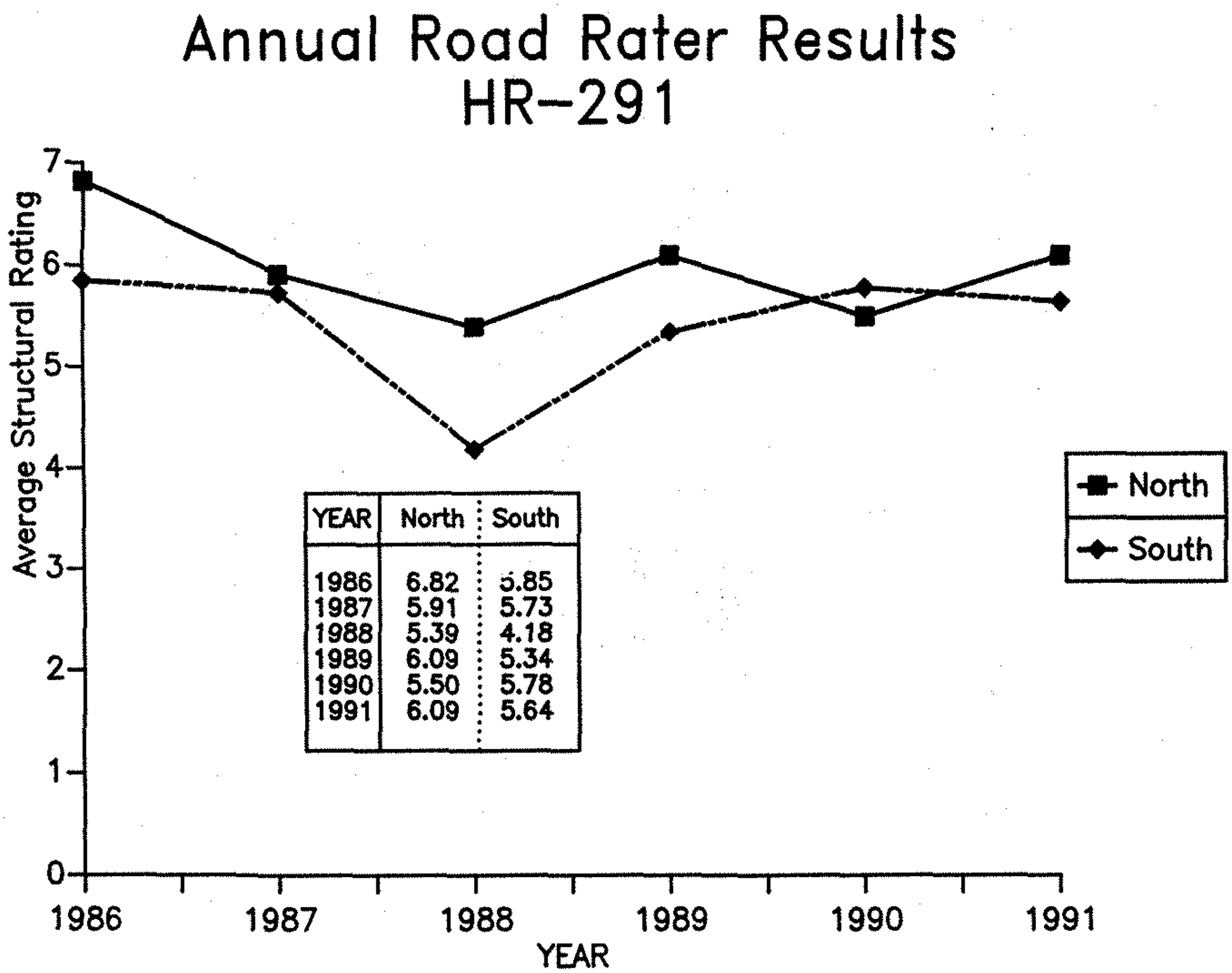


Figure 3

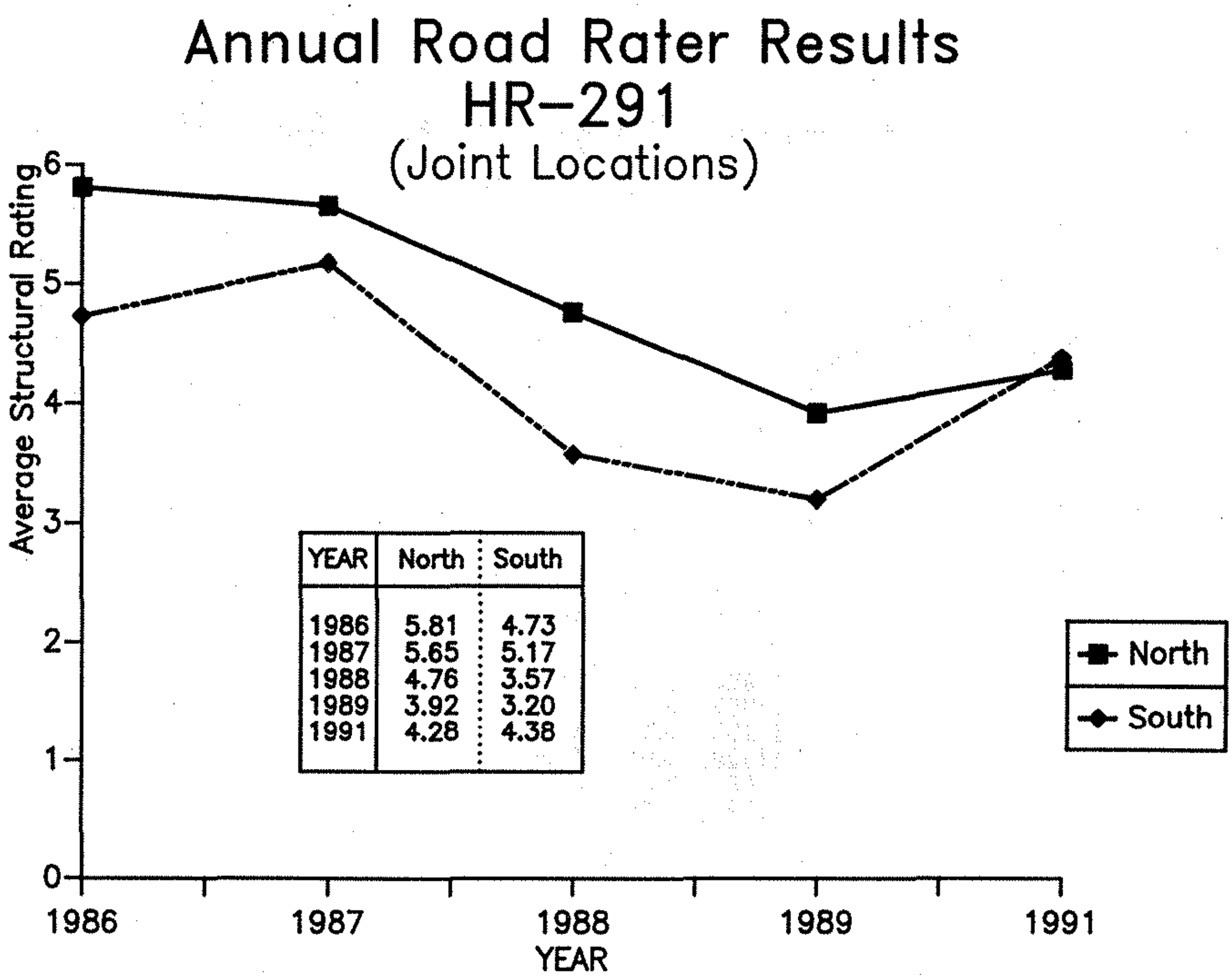

Annual Road Rater Results
HR-291
(Joint Locations)
Average Structural Rating
0
1
2
3
4
5
6
YEAR North South
1986 5.81 4.73
1987 5.65 5.17
1988 4.76 3.57
1989 3.92 3.20
1991 4.28 4.38
North
South
1986
1987
1988
1989
1991
YEAR

Figure 4

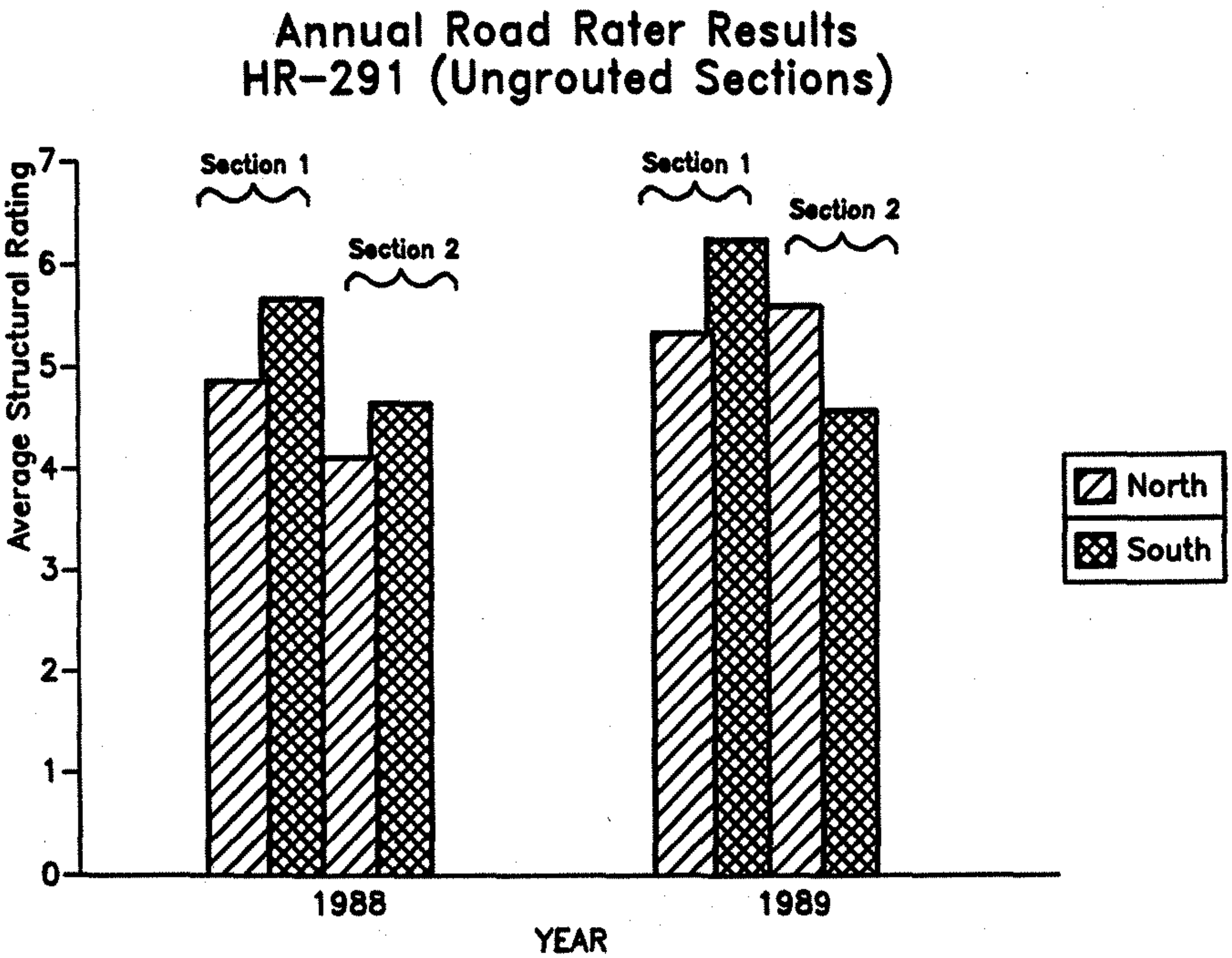


Figure 5

Profilometer Testing

The Iowa Department of Transportation uses a California-Type 25-Foot Profilograph to test pavements and bridge decks for smoothness. The 25-Foot Profilograph is a rolling straight edge essentially measuring vertical deviations from a moving 25-foot reference plane. The pavement profile is graphically recorded on a profilogram from which the Profile Index is determined and is reported in inches/mile.

Profilometer testing in July of 1988 reflects a high degree of roughness, possibly a result of the apparent debonding at the joints of Section 1. The roughness of Section 1 was twice that of either Section 2 or the grouted overlay area separating the sections (Table II). Testing done in December of 1991 reinforces the fact that Section 1 still has a roughness value in both the northbound and southbound lanes greater than in Section 2 (Table II). The effect of this roughness on the driver seems to be negligible, however.

Table II
(1988)

Section	Stationing	Roughness, in./mi. (cm/km) Southbound	Northbound
1	419+75 to 422+25	23.23 (36.66)	20.06 (31.66)
Intermediate	422+25 to 443+25	6.79 (10.7)	10.31 (16.27)
2	443+25 to 445+75	9.50 (15.0)	9.50 (15.0)
	(1991)		
1	419+75 to 422+25	25.30 (39.93)	13.70 (21.62)
Intermediate	422+25 to 443+25	10.60 (16.73)	14.84 (23.43)
2	443+25 to 445+75	5.30 (8.36)	6.30 (9.94)

DISCUSSION AND SUMMARY

A bonded pcc overlay can, in many cases, extend the pavement service life, lower life-cycle costs, and increase the structural capacity of the pavement. Although the initial cost may be higher than for an AC overlay, possible reduced maintenance costs and greater pavement life are reasons that bonded overlays can be a viable resurfacing alternative. If sufficient bonding can be achieved and maintained without using grout, even more savings in time and money can be realized.

While the pavement shows little sign of surface distress, the apparent debonding occurring at the joints in Section 1 is a cause for concern. It is entirely possible that horizontal and vertical movements of the pavement contribute to debonding. Had in-depth documentation been done on the original pavement after full-depth or patch repairs, any contributing causes of deterioration in the overlay by the underlying slab could be ascertained.

CONCLUSIONS

From this research it can be concluded that:

1. Adequate bond (>200 psi or 1380 kPa) between the original slab and pcc overlay can be achieved both with and without grout.

2. What little debonding (12 inches or .30 m) on each side of the ungrouted joints that has occurred in Section 1 has not worsened over the past two years.

3. The lack of debonding at the joints in Section 2 indicates that the non-use of grout here has performed well.

ACKNOWLEDGEMENT

This research project was suggested by the Iowa Concrete Paving Association and sponsored by the Iowa Department of Transportation through the Highway Research Advisory Board. Partial funding for this project was from the Secondary Road Research Fund in the amount of $14,200.

The author wishes to extend appreciation to Wendell Folkerts, Wapello County Engineer; Gordon Smith, Iowa Concrete Paving Association; and the Iowa DOT for their support in conducting this project. Central Paving Corporation also deserves recognition for their cooperation on the project. Finally, many thanks go to Kathy Davis, Chris Anderson, and Vernon Marks of the Iowa DOT Materials Office for their assistance in writing this report.

REFERENCES

1. Lane, John, "Performance of Nongrouted Thin Bonded PCC Overlays," Construction Report, Iowa Highway Research Board, HR-291, August 1986.

2. Peshkin, D. G., Mueller, A. L., "Field Performance and Evaluation of Thin Bonded Overlays," Transportation Research Record 1286, TRB, National Research Council, Washington, D.C. 1990, pp 84-94.

Appendix A
Method of Test for Determining the Shearing Strength of Bonded Concrete

IOWA DEPARTMENT OF TRANSPORTATION

Office of Materials

METHOD OF TEST FOR DETERMINING THE SHEARING STRENGTH OF BONDED CONCRETE

Scope

This method covers the procedure used in determining the shearing strength at the bonded interface between new and old concrete. The test is normally conducted on cores drilled from completed structures or pavements.

Procedure

A. Apparatus

1. Testing jig to accommodate a 4" diameter specimen. The jig is designed to provide a direct shearing force at the bonded interface.

2. Hydraulic testing machine capable of applying a smooth and uniform tensile load. The accuracy of the reading shall be with ± 1.0% of the indicated load.

B. Test Specimens

1. Four-inch-diameter cores are the normal test specimen. Unless otherwise specified the cores are tested in an "as received" condition.

C. Test Procedure

1. Placing the specimen

(a) Place the specimen in the testing jig in such a manner that the bonded interface is placed in the space between the main halves of the jig.

(b) In the event that the interface is irregular and cannot entirely be placed within the specified space, the interface will be placed as close as practical and a special notation made.

(c) Carefully align the testing jig in the testing machine with the central axis of the jig in the center of the testing machine.

2. Rate of Loading

(a) Apply the tensile load continuously and without shock. Apply the load at a constant rate within the range of 400 to 500 psi per minute.

(b) Continue the loading until the specimen fails, and record the maximum load carried by the specimen during the test.

D. Calculations

1. Calculate the shear bond strength of the specimen by dividing the maximum load carried by the specimen during the test by the cross-sectional area and express the result to the nearest psi.

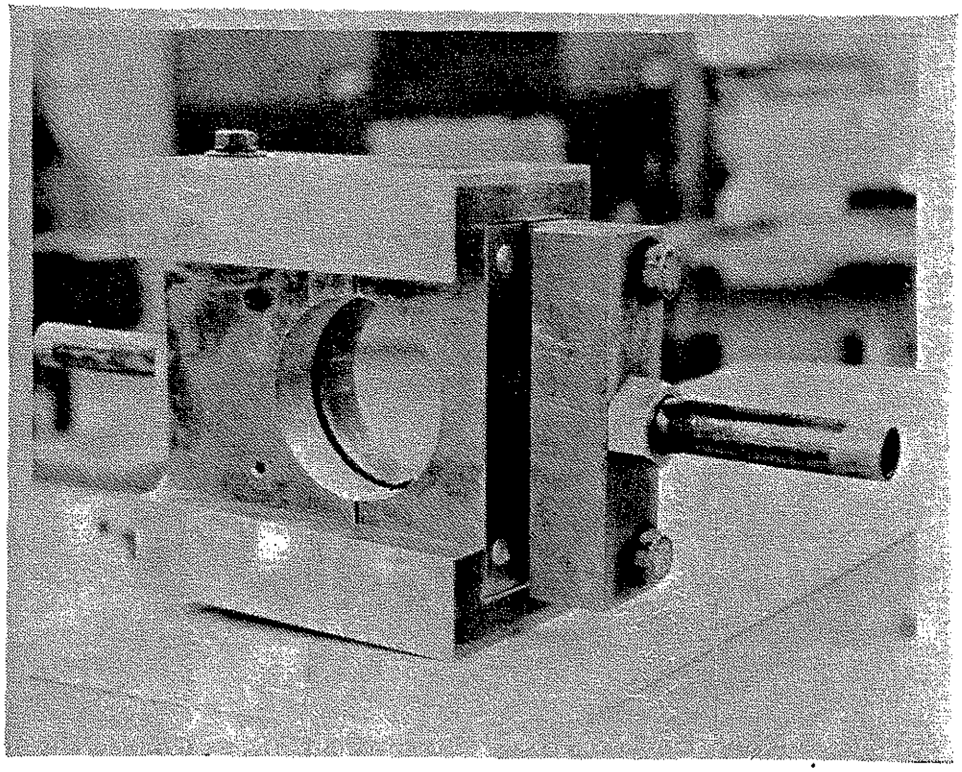


Figure 1 Testing Jig

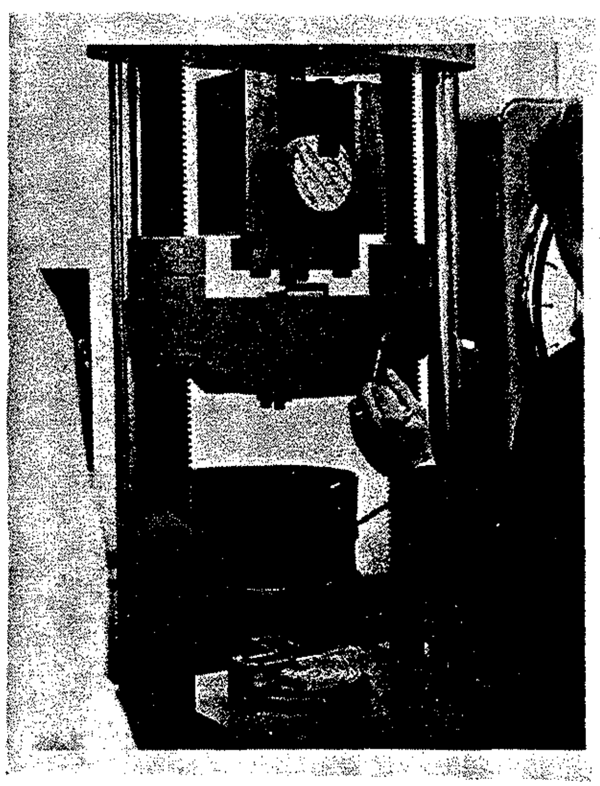


Figure 2 Hydraulic Testing Machine,
Testing Jig and Specimen

Appendix B
Specification for Thin-Bonded Portland Cement Concrete Overlay

Section 2310. Thin-Bonded Portland Cement Concrete Overlay

2310.01 DESCRIPTION. This work consists of a PCC resurfacing overlay of an existing PCC pavement, and it may include associated patching and widening work.

2310.02 MATERIALS. All materials shall meet the requirements for the respective items in Part IV of the Standard Specifications, with the following modifications:

A. Cement. Article 4101 shall apply. The use of Type III cement will not be permitted.

B. Aggregate. Sections 4110 and 4115 shall apply. Coarse aggregate shall be of gradation 3 or 5 and of the durability class specified for PCC pavement; however, aggregate of Class I durability will not be permitted.

Unless otherwise specified, the coarse aggregate shall be crushed limestone.

C. Concrete. Mix No. C-4WR, as specified in 2301.04, shall be used for resurfacing.

D. Grout for bonding new concrete to previously placed concrete shall consist of equal parts by weight of portland cement and concrete sand, mixed with sufficient water to form a stiff slurry. The consistency shall be such that it can be applied with a stiff brush or broom to the concrete in a thin, even coating that will not run or puddle in low spots. The grout shall be agitated prior to and during its use. The cement-to-water contact time of the grout shall not exceed 90 minutes before it is placed. An equivalent grout of portland cement and water, applied by pressure spray, may be substituted with approval of the Engineer.

E. Joint Filler and Sealer shall meet requirements of Section 4136.02A. For a part of this material, a white or gray filler may be required by 2310.08E.