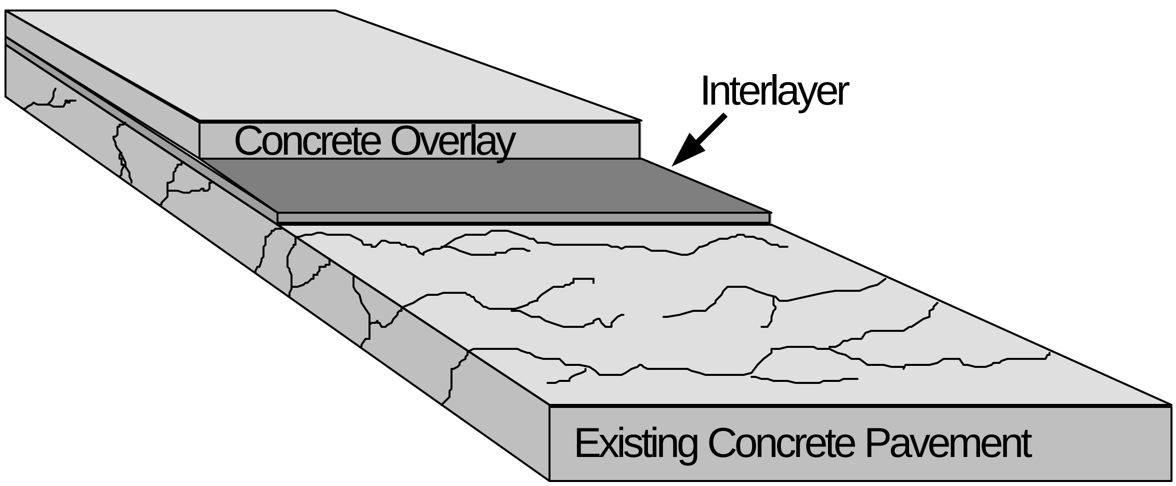
PERFORMANCE OF AN UNBONDED CONCRETE OVERLAY ON I-74



PHYSICAL RESEARCH REPORT NO. 140
APRIL 2002

Illinois Department of Transportation
Bureau of Materials and Physical Research
126 East Ash Street / Springfield, Illinois / 62704-4766

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
IL-PRR-140		

4. Title and Subtitle	5. Report Date
Performance of an Unbonded Concrete Overlay on I-74	April 2002
	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s) Laura B. Heckel, P.E.	Physical Research Report No. 140

9. Performing Organization Name and Address	10. Work Unit (TRAIS)
Illinois Department of Transportation Bureau of Materials and Physical Research 126 East Ash Street Springfield, Illinois 62704	IHR-001
	11. Contract or Grant No. HPR-25-001-02-1
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Illinois Department of Transportation Bureau of Materials and Physical Research 126 East Ash Street Springfield, Illinois 62704	Final Report, 1995 to 2001
	14. Sponsoring Agency Code

15. Supplementary Notes

STUDY TITLE: UNBONDED PORTLAND CEMENT CONCRETE OVERLAYS. This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. Abstract

In Illinois, the typical rehabilitation for a concrete pavement is full-depth patching of the distressed concrete, and overlaying the pavement with 3.25 inches of bituminous concrete. In cases where there are poor joints or extensive durability cracking of the existing concrete pavement, a 5-inch bituminous concrete overlay may be placed. When bituminous concrete overlays reach the end of their service lives, common distresses are reflective longitudinal and transverse cracking, reflective cracks from transverse joints and patches, and reflective D-cracking. Once concrete pavements have deteriorated to the point where the performance of a standard bituminous concrete overlay is questionable, constructing an unbonded concrete overlay may be considered. An unbonded concrete overlay leaves the existing concrete pavement and any bituminous concrete overlays in place. A new concrete pavement is constructed on top of the existing bituminous concrete overlay or a new bituminous concrete interlayer. In 1995, the Illinois Department of Transportation constructed an unbonded concrete overlay on Interstate 74 east of Galesburg. The existing pavement was a 7-inch continuously reinforced concrete pavement, with a 4-inch bituminous aggregate mixture (BAM) base. The existing bituminous concrete overlay ranged from 3 to 4.5 inches thick. The unbonded concrete overlay is 9 inches thick. This report describes the performance of this project through 2001, and the status of unbonded concrete overlays in Illinois.

17. Key Words	18. Distribution Statement
Unbonded Concrete Overlay, Continuously Reinforced Concrete Pavement (CRCP), D-Cracked Pavements, Rehabilitation	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	17	

PERFORMANCE OF AN UNBONDED CONCRETE OVERLAY ON I-74

Final Report

by:

Laura B. Heckel, P.E.

Design Technology Engineer

ILLINOIS DEPARTMENT OF TRANSPORTATION

BUREAU OF MATERIALS AND PHYSICAL RESEARCH

SPRINGFIELD, ILLINOIS

APRIL 2002

TABLE OF CONTENTS

ACKNOWLEDGMENTS

The author thanks Matt Mueller, LaDonna Rowden, and Tom Winkelman for reviewing this report. The author also thanks personnel from the Bureau of Materials and Physical Research Operations sub-unit for providing performance testing of the pavement.

DISCLAIMER

The content of this report reflects the views of the author, who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Illinois Department of Transportation. This report does not constitute a standard, specification, or regulation.

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The Illinois Department of Transportation (IDOT) is responsible for the maintenance and rehabilitation of approximately 17,000 miles of pavement. Most of these pavements, 16,000 miles, were constructed as concrete pavements; jointed plain, jointed reinforced, or continuously reinforced. The majority of these pavements have reached the end of their original service lives and have been rehabilitated at least once, and many pavements more than once.

In Illinois, the typical rehabilitation for a concrete pavement is full-depth patching of the distressed concrete, followed by overlaying the pavement with 3.25 inches of bituminous concrete. In cases where there are poor joints or extensive durability cracking (D-cracking) of the existing concrete pavement, a 5-inch bituminous concrete overlay may be placed. When overlays reach the end of their service lives, common distresses are reflective longitudinal and transverse cracking, reflective cracks from transverse joints and patches, and reflective D-cracking. The typical life of a bituminous concrete overlay is 10 to 12 years (1).

Once concrete pavements have deteriorated to the point where the performance of a standard bituminous concrete overlay is questionable, constructing an unbonded concrete overlay may be considered. An unbonded concrete overlay leaves the existing concrete pavement and any bituminous concrete overlays in place. A new concrete pavement is constructed on top of the existing bituminous concrete overlay or a new bituminous concrete interlayer. The unbonded concrete overlay can be either jointed or continuously reinforced (2, 3, 4).

In 1995, IDOT constructed a 9-inch thick unbonded concrete overlay on Interstate 74 (I-74) east of Galesburg, in Knox County. The project is on westbound I-74, between mileposts 53.79 and 61.73. The existing concrete pavement was a 7-inch continuously reinforced concrete (CRC), with a 4-inch bituminous aggregate mixture (BAM) base. The existing bituminous concrete overlay ranged from 3 to 4.5 inches thick. The concrete was severely D-cracked and had many punchouts; and the bituminous concrete overlay exhibited transverse, longitudinal, and reflective cracking. In several places, the pavement had been repaired with full-depth concrete patches poured to the surface of the overlay.

Preparation of the existing pavement prior to overlay consisted of cold milling full-depth patches to the level of the original pavement, and replacement with bituminous concrete level binder to match the surrounding bituminous concrete overlay. Prior to setting the reinforcement for the new CRCP, the bituminous concrete was whitewashed to prevent excessive heating of the bottom of the new concrete, which can cause a fast set on the bottom of the new pavement. The remaining construction operation was the same as paving new concrete pavement. An earlier report contains additional details of the planning, design, and construction of the unbonded concrete overlay (5).

The performance measures of the unbonded concrete overlay include traffic consumption, Condition Rating Survey (CRS) values, visual distress surveys, International Roughness Index (IRI), and Falling Weight Deflectometer (FWD) data. This report describes the performance of this project through 2001, and the status of unbonded concrete overlays in Illinois.

TRAFFIC CONSUMPTION

Traffic is an important input to the pavement design process. To ensure a reasonable pavement design, the designer is required to make projections of the traffic mix, volume, and rate of growth over the expected life of the pavement. To quantify traffic, average daily traffic (ADT) data are used to determine the number of passenger vehicles, single unit trucks, and multiple unit trucks.

Using the ADT data, the Equivalent Single Axle Loads (ESALs) per year are calculated. These values are summed to determine the cumulative ESALs to date. Percent consumption refers to the amount of pavement design life consumed, based on actual traffic loading, and is calculated as follows:

$$\text{Percent Consumption} = \frac{\text{Cumulative ESALs}}{\text{Design traffic factor}} * 100$$

The design traffic factor is the number of ESAL loadings the pavement can withstand with a given level of reliability, and for a given performance level, without requiring major rehabilitation. Because the design reliability is typically 95 to 97 percent, most pavements should be able to withstand a greater number of ESAL loadings (greater than 100 percent consumption) and still provide an adequate level of service.

In 2001, there were 8,700 passenger vehicles, 500 single-unit trucks, and 3,500 multiple-unit trucks traveling the pavement on the average day, or approximately 1.1 million ESALs in one year in one direction. As of December 31, 2001, 7.6 million ESALs had accumulated on the unbonded concrete overlay. The design traffic factor was 24 million ESALs, so 31.6 percent of the design traffic has been consumed. Assuming a traffic growth rate of 3 percent per year, the traffic on the unbonded concrete overlay will reach the design traffic 18 years after construction.

CONDITION RATING SURVEY AND VISUAL DISTRESS SURVEYS

IDOT performs the condition rating survey on every interstate pavement section, every two years. The rating ranges from 9.0 to 1.0, with 9.0 being new construction and 1.0 representing total failure of the pavement. This rating is used to decide when sections of roadway need rehabilitation. The CRS for the unbonded concrete overlay was 8.3 in 2000, indicating the pavement is in excellent condition five years after construction.

Visual distress surveys were conducted by personnel from the Bureau of Materials and Physical Research. The surveys were performed on 500-foot sections at each milepost, for a total of 4,000 feet surveyed. Describing low severity cracks in a CRCP is tenuous, due to the fact that cracking is necessary on CRCPs. The Bureau personnel do not identify a transverse crack as low severity, other than for determining spacing, until it begins to widen beyond a hairline width. In 2001, a small number of cracks in the 4,000 feet surveyed had begun to widen and were considered low severity. There were no medium or high severity cracks in any year.

To a point, the more transverse cracks there are, the better, because many narrow cracks are preferred to fewer, wider cracks. Table 1 contains the average crack spacing in the driving lane in each year. The crack spacing evident on this project is very good (6).

Table 1. Summary of Visual Distress Surveys.

Year Surveyed	Age (Years)	Crack Spacing (Feet)
1997	2	3.1
1998	3	3.0
1999	4	2.8
2000	5	2.3
2001	6	2.3

At one spot within the 4,000 feet surveyed, the cracks had come together to form an early stage of a punchout. Figure 1 shows this area of distress. A few additional punchouts outside of the 4,000 feet surveyed were also noticed. Each punchout area is so small that patching has not been necessary.

Figure 1. Early Stage of Punchout in Unbonded Concrete Overlay in 2001.

INTERNATIONAL ROUGHNESS INDEX DATA

Roughness data were collected on the unbonded concrete overlay using IDOT's Video Inspection Vehicles (VIVs). This device measures surface roughness in inches per mile. The IRI values, which represent what a driver would feel as s/he drove down the road, are calculated from the data collected with the VIVs. The lower the roughness value, the better the ride quality. An IRI around 60 inches per mile is typical for new concrete pavements.

In 2000, the average IRI for the unbonded concrete overlay was 70 inches per mile. This shows that the roughness of the overlay is still at a near-new level.

DEFLECTION DATA

Deflection data were collected on the unbonded concrete overlay using IDOT's Dynatest 8002 FWD, a non-destructive loading device capable of exerting a load impulse comparable in magnitude and duration to moving truck loads (7).

Data analyzed include deflection under the load, deflection basin area, subgrade resilient modulus (E_{RI}), and load transfer efficiency (LTE) across cracks. Deflection data under the load (D0) were normalized to reflect a 9,000-pound load to allow for direct comparison of results. Deflections under 6 mils for concrete pavements are considered excellent. The lower the deflection, the stiffer the pavement cross section. For this pavement, average deflection data were collected at cracks.

The deflection basin area (Area) represents the ability of the pavement to spread an applied load. The units for deflection basin area are inches, because true area is divided by the deflection under the load to allow for comparison. Areas of approximately 30 inches are typical for concrete pavements. The higher the deflection basin area, the greater the load-spreading ability of the pavement. Area data were collected between cracks.

Subgrade resilient modulus (E_{RI}) values were calculated using concepts and algorithms developed at the University of Illinois (8). A higher E_{RI} represents a more stable subgrade. An E_{RI} greater than 10 ksi is considered good support for concrete pavements. E_{RI} data were collected between cracks.

Load transfer efficiency (LTE) across cracks is calculated by dividing the deflection on the far side of the crack, by the deflection under the load. The closer the LTE is to 100 percent, the better the concrete and steel are transmitting the load across the cracks.

The deflection data presented are averages for the section in the year of deflection testing. The temperature shown in the table is taken 4 inches below the surface of the pavement.

Table 2. Deflection Data.

Date	Temp. (° F)	D0 (Mils)	Area (inches)	E_{RI} (ksi)	LTE (%)
7/95	90	2.0	31.0	17.4	NC
8/96	77	2.2	31.6	15.1	NC
7/97	85	2.4	31.4	14.3	92.6
4/99	56	2.1	31.0	17.8	92.6
7/01	94	2.3	30.8	16.3	91.6

Note: NC indicates data was not collected.

The average deflection under the load has been unchanged over the last six years, regardless of temperature at the time of testing. All the deflection results are very good and show no deterioration to date.

STATUS OF UNBONDED CONCRETE OVERLAYS

Unbonded concrete overlays were constructed on a few pavements in Illinois in the late 1960s and early 1970s. In 2000, another unbonded concrete overlay was constructed on Interstate 88, and an additional one will be constructed on Interstate 70 in 2002. A policy has not been developed for the use of unbonded concrete overlays. This rehabilitation option should be considered whenever a reconstruction alternative to a standard bituminous concrete overlay is desired.

Design Considerations

The design thickness is determined by using the CRCP design procedure in the Bureau of Design and Environment (BD&E) Manual, Chapter 54 (1), then subtracting one inch. The bituminous concrete interlayer, usually the existing overlay, should be at least 3 inches thick after crown corrections have been made, and should be whitewashed prior to placing reinforcement on the bituminous concrete interlayer. The BMPR and BD&E review proposed projects.

There are several things to consider when evaluating the possibility of constructing an unbonded concrete overlay. The first consideration is the number of at-grade and overhead structures throughout the length of the project. The elevation of the new concrete pavement is higher than the existing pavement. Therefore, at-grade and overhead structures should be raised, or the existing pavement should be removed and replaced near these structures. If structures cannot be raised, and a high percentage of the existing pavement would need to be reconstructed around the structures, an unbonded concrete overlay may not be the best option for rehabilitation.

The presence of a bituminous concrete overlay may affect the decision to construct an unbonded concrete overlay. If there is no overlay, a bituminous concrete interlayer will need to be constructed.

Drainage should also be considered. The higher elevation of the pavement necessitates a change in the ditch grade lines. Additional right-of-way may be required to provide the proper slopes for the ditches. If right-of-way cannot be purchased, consideration should be given to installing storm drains, or performing a different type of rehabilitation.

Unbonded concrete overlays are a good option if a high performance level is desired. The old pavement is left in place, causing these overlays to be less expensive than complete removal and replacement. If the pavement has been previously overlaid with bituminous concrete, the bituminous concrete overlay can remain in place, to function as the interlayer between the old and new concrete pavements.

Cost Considerations

In the 1996 report, the costs of the I-74 unbonded concrete overlay were compared to the costs of a full reconstruction of a section of I-80 performed in the same fiscal year (5). The unbonded concrete overlay was found to be considerably less expensive on a 2-lane mile basis for several reasons. There was already a bituminous concrete overlay in place, so only crown corrections needed to be performed. The concrete pavement was thinner, because of the one inch credit given to the underlying pavement. There was no removal of existing concrete, and no subbase or base constructed. Overhead and at-grade structures were not considered in this analysis.

SUMMARY AND CONCLUSIONS

In 1995, a 9-inch thick unbonded concrete overlay was constructed on I-74 east of Galesburg. The overlay was placed on the existing bituminous concrete overlay of the 7-inch thick CRCP. Performance has been monitored since construction through traffic consumption, CRS values, visual distress surveys, IRI, and deflection testing. Only 31 percent of the design traffic has been consumed, indicating the design traffic will be reached in approximately 18 years, assuming a growth rate of 3 percent per year. The CRS, IRI, and deflection results have been excellent over the 6-year life of the overlay. Transverse cracking increased in 2001, but is still low severity. No maintenance or patching of the unbonded concrete overlay has been necessary.

Unbonded concrete overlays provide an excellent rehabilitation option, when the existing pavement is severely deteriorated and the performance of a standard patch and bituminous concrete overlay is questionable. Because the thickness and cross section characteristics are similar to new construction, performance level and design life are also similar to new construction. Costs for constructing an unbonded concrete overlay are lower than for complete removal and replacement of the pavement.

REFERENCES

1. Illinois Department of Transportation. Bureau of Design and Environment Manual. Bureau of Design and Environment, Illinois Department of Transportation, Springfield, Illinois, November 1999.

2. Voight, G. F., Michael I. Darter, and Sam Carpenter. "Field Performance Review of Unbonded Jointed Concrete Overlays," In *Transportation Research Record 1227*, TRB, National Research Council, Washington , D.C., 1989, pp. 12-23.

3. "Portland Cement Concrete Resurfacing," NCHRP Synthesis 204, TRB, National Research Council, Washington , D.C., 1994.

4. "Evaluation of Unbonded Portland Cement Concrete Overlay," NCHRP Report 415, TRB, National Research Council, Washington , D.C., 1999.

5. McNeal, Amy. "Planning, Design and Construction of an Unbonded Concrete Overlay." Physical Research Report #122, Bureau of Materials and Physical Research, Illinois Department of Transportation, July 1996.

6. Yoder, E. J. and M. W. Witczak. "Principles of Pavement Design." John Wiley and Sons, Inc., New York, 1975.

7. Heckel, Laura. "Performance Monitoring of Mechanistically-Designed Pavements." Bureau of Materials and Physical Research, Illinois Department of Transportation, Springfield, Illinois, September 2000.

8. Thompson, M. R. ILLI-PAVE Based NDT Analysis Procedures. In *Nondestructive Testing of Pavements and Backcalculation of Moduli*. ASTM STP 1026, A. J. Bush III and G. Y. Baladi, Editors, ASTM, Philadelphia, 1989, pp. 487-501.