Louisiana Transportation Research Center

Final Report 595

Evaluation of Dowel Bar Alignment and Effect on Long-term Performance of Jointed Pavement

by

Tyson Rupnow, Ph.D., P.E.
Patrick Icenogle, P.E.
Zachary Collier, E.I.

LTRC

4101 Gourrier Avenue | Baton Rouge, Louisiana 70808
(225) 767-9131 | (225) 767-9108 fax | www.ltrc.lsu.edu

TECHNICAL REPORT STANDARD PAGE

1. Report No. **FHWA/LA.17/595**	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle **Evaluation of Dowel Bar Alignment and Effect on Long-term Performance of Jointed Pavement**	**5. Report Date** May 2018 **6. Performing Organization Code** LTRC Project Number: 14-1C SIO Number: 30001440	
7. Author(s) Tyson D. Rupnow, Patrick Icenogle, Zachary Collier	**8. Performing Organization Report No.**	
9. Performing Organization Name and Address Louisiana Transportation Research Center 4101 Gourrier Avenue Baton Rouge, LA 70808	**10. Work Unit No.** **11. Contract or Grant No.**	
12. Sponsoring Agency Name and Address Louisiana Department of Transportation and Development P.O. Box 94245 Baton Rouge, LA 70804-9245	**13. Type of Report and Period Covered** **Final Report** **06/13 – 12/17** **14. Sponsoring Agency Code**	

15. Supplementary Notes

Conducted in Cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

Dowel bars are the current preferred method for providing load transfer for jointed plain concrete pavements (JPCP). For proper load transfer to occur, the dowels must be placed properly, i.e., in the middle of the slab, horizontal to the grade, and in the direction of traffic flow. This project evaluated JPCP performance with relation to dowel bar alignment utilizing the new MIT-SCAN2-BT technology.

Four to eight jointed concrete pavements of each of the following ages were measured: 0-10 years, 10-20, years, and 20+ years of age to determine the effects of dowel bar misalignment on pavement performance indicators such as faulting, load transfer, and ride quality. For each project, about 5 percent of the joints were tested, (about 15 joints per mile). The joints were tested in groups of five at 0.3-, 0.3-, and 0.4-mile increments. Every joint on the newly constructed I-49 corridor from LA1 to the Arkansas state line was measured.

The results of this project show that the MIT-SCAN2-BT device is accurate, but the flexible track is fragile and will need repairs in extended testing scenarios. Testing rates range from 32-45 joints per hour for full width pavement sections in a closed road condition. The pavement surface must be free of debris and measurements should be conducted prior to application of raised pavement markers.

Pavements constructed over the past 30 years that contain dowel bars in the joint detail are performing well with regards to measurable faulting. Measured joints were constructed with no horizontal skew, vertical translation, vertical tilt, or horizontal translation. The results indicated that the pavement sections should not exhibit joint lock due to skew or tilt.

The MIT-SCAN2-BT device is very capable of locating and measuring dowel bars and assemblies. It is also capable of determining whether or not a bar is missing, or if the load transfer device is something other than a dowel bar. The results also indicate that the effect of longitudinally translated dowel bars is negligible. Acceptable long-term performance was observed in joints with less than 4 in. of embedment and some joints with 2.5 to 3 in. of embedment. The Department's current dowel placement specifications lead to acceptable long-term joint performance.

17. Key Words concrete pavement joints, DBI, dowel basket, dowel misalignment		**18. Distribution Statement** **Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161.**	
19. Security Classif. (of this report)	**20. Security Classif. (of this page)**	21. No. of Pages 41	22. Price

Project Review Committee

Each research project will have an advisory committee appointed by the LTRC Director. The Project Review Committee is responsible for assisting the LTRC Administrator or Manager in the development of acceptable research problem statements, requests for proposals, review of research proposals, oversight of approved research projects, and implementation of findings.

LTRC appreciates the dedication of the following Project Review Committee Members in guiding this research study to fruition.

LTRC Manager

Samuel Cooper, III, Ph.D., P.E.

Materials Research Manager

Members

Chris Abadie

Hector Santiago

John Eggers

Bill Temple

Mike Vosburg

Phil Graves

Darrel Goza

Directorate Implementation Sponsor

Christopher P. Knotts, P.E.

DOTD Chief Engineer

Evaluation of Dowel Bar Alignment and Effect on Long-term Performance of Jointed Pavement

by

Tyson Rupnow, Ph.D., P.E.
Patrick Icenogle, P.E.
Zachary Collier, E.I.

Louisiana Transportation Research Center
4101 Gourrier Avenue
Baton Rouge, LA 70808

LTRC Project No. 14-1C
SIO No. 30001440

conducted for

Louisiana Department of Transportation and Development
Louisiana Transportation Research Center

May 2018

ABSTRACT

Dowel bars are the current preferred method for providing load transfer for jointed plain concrete pavements (JPCP). For proper load transfer to occur, the dowels must be placed properly, i.e. in the middle of the slab, horizontal to the grade, and in the direction of traffic flow. This project evaluated JPCP performance with relation to dowel bar alignment utilizing the new MIT-SCAN2-BT technology.

Four to eight jointed concrete pavements of each of the following ages were measured: 0-10 years, 10-20, years, and 20+ years of age to determine the effects of dowel bar misalignment on pavement performance indicators such as faulting, load transfer, and ride quality. For each project, about 5 percent of the joints were tested, (about 15 joints per mile). The joints were tested in groups of five at 0.3-, 0.3-, and 0.4-mile increments. Every joint on the newly constructed I-49 corridor from LA1 to the Arkansas state line was measured.

The results of this project show that the MIT-SCAN2-BT device is accurate, but the flexible track is fragile and will need repairs in extended testing scenarios. Testing rates range from 32-45 joints per hour for full width pavement sections in a closed road condition. The pavement surface must be free of debris and measurements should be conducted prior to application of raised pavement markers.

Pavements constructed over the past 30 years that contain dowel bars in the joint detail are performing well with regards to measurable faulting. Measured joints were constructed with no horizontal skew, vertical translation, vertical tilt, or horizontal translation. The results indicated that the pavement sections should not exhibit joint lock due to dowel skew or tilt.

The MIT-SCAN2-BT device is very capable of locating and measuring dowel bars and assemblies. It is also capable of determining whether or not a bar is missing, or if the load transfer device is something other than a dowel bar. The results also indicate that the effect of longitudinally translated of dowel bars is negligible. Acceptable long-term performance was observed in joints with less than 4 in. of embedment and some joints with 2.5 to 3 in. of embedment. The Department’s current dowel placement specifications lead to acceptable long-term joint performance.

ACKNOWLEDGMENTS

The U.S. Department of Transportation, Federal Highway Administration (FHWA), Louisiana Department of Transportation and Development (DOTD), and Louisiana Transportation Research Center (LTRC) financially supported this research project. The efforts of Greg Tullier, Norris Rosser, and Craig Johnson in the concrete laboratory are greatly appreciated. The efforts of various maintenance crews statewide providing traffic control during testing efforts are also greatly appreciated.

IMPLEMENTATION STATEMENT

The results show that dowel bar misalignment is generally not a concern for present and past pavements constructed for DOTD. In general, concerning longitudinal translation, a dowel bar embedment length of 4 in. is sufficient to provide load transfer, with several joints exhibiting good performance at 15+ years of age with 2.5 to 3 in. of embedment. The authors do not recommend implementing the use of the MIT-SCAN2-BT for quality control or quality assurance purposes due to the findings of this study.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Dowel bars are the current preferred method for providing load transfer for jointed plain concrete pavements (JPCP). For proper load transfer to occur, the dowels must be placed properly, i.e. in the middle of the slab, horizontal to the grade, and in the direction of traffic flow. DOTD has rarely questioned dowel bar alignment due to the inability to measure dowel bars and due to the non-materialization of dowel bar alignment related pavement distress.

This project evaluated JPCP performance with relation to dowel bar alignment utilizing the MIT-SCAN2-BT. The MIT-SCAN2-BT, shown in Figure 1, uses magnetic tomography to locate dowel bars. A series of five magnets are arranged and calibrated such that all types of dowel misalignments can be measured. The device is setup on guide rails centered over a pavement joint, then pulled along the joint broadcasting data via Bluetooth to a handheld computer. The handheld is able to lightly process data in real time and show estimated values and contour plots. Final data processing and reporting are completed using a PC using the supplied software.

Figure 1
MIT-SCAN2-BT

Literature Review

Dowel bar misalignment can occur in a variety of ways, as shown in Figure 2. Horizontal translation in wheel paths can reduce load transfer if not properly spaced across a wheel path. Longitudinal translation will reduce embedment length and could lead to loss of load transfer. Vertical translation could result in insufficient cover and lead to spalling and loss of load transfer. Skewed and tilted bars may restrain expansion and contraction from temperature and lead to spalling, transverse cracking, and reduced load transfer [*1*].

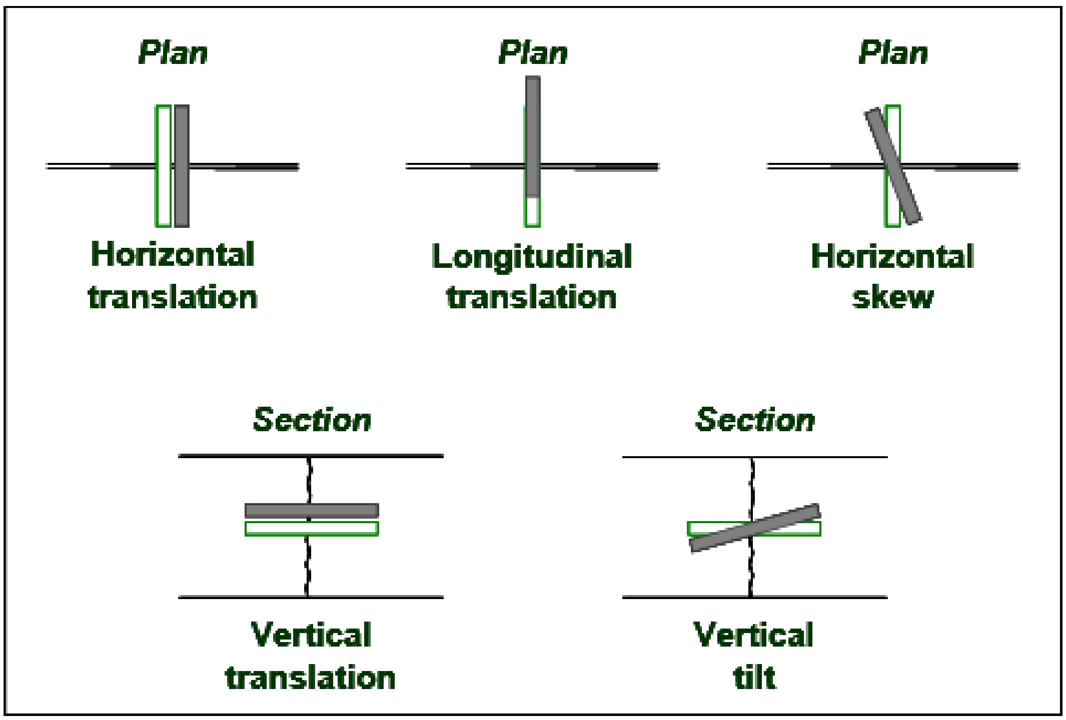

Figure 2
Types of dowel bar misalignment [*1*]

NCHRP Report 637 compared performance to misalignment on numerous projects from various states, many with no distresses. The projects with minor shallow surface spalling were determined to be caused by saw cut timing, not dowel bar alignment. Load transfer and faulting were found to be statistically similar for longitudinal translation of less than 0.5 in. and longitudinal translations from 2.0-3.0 in. The research concluded that longitudinal translations of +/- 2 in. of 18-in. dowels, vertical translation of +/- 0.5 in. of 12 in. pavement thickness, and skew and tilt of 0.5 in. of 18-in. dowels have no significant effects on pavement performance [*1*].

Leong showed spalling failures from vertical tilt greater than 1 in. and skews greater than 3 in. [*2*]. Odden et al. showed slabs with 2 in. vertical of cover performed as well as 3 in. of vertical cover and Georgia DOT found no pavement distress related to dowel alignment for a pavement constructed in 1983 at the end of a three-year study [*3-4*].

Minnesota DOT monitored a section with dowel embedment lengths of 2.5 in. or less. Twelve years after construction, they observed that the extremely small embedment lengths contributed to premature failure. The report concluded that a minimum of 2.5 in. of embedment is needed for adequate load transfer and prevent significant faulting [*5*].

A Concrete Pavement Technology Program (CPTP) Tech Brief highlighted best practices for dowel bar alignment. The acceptance criteria noted for 18-in. dowels as follows: horizontal/vertical rotational alignment less than 0.6 in., longitudinal shift less than 2 in., and within 1 in. of mid-depth of thickness [*6*].

A 2013 American Concrete Pavement Association (ACPA) guide specification gives recommended quality assurance (QA) and required action triggers for dowel bar alignment as follows: longitudinal translation QA > 2 in. and Req. Action > 5 in. (or 4 in. embedment), vertical translation QA > 1 in. and Req. Action if concrete cover is less than 2.5 in., horizontal translation QA > 2 in. and Req. Action > 3 in., and skew and tilt QA > 0.6 in. and Req. Action if single dowel misalignment (sqrt(Skew^2 + Tilt^2)) > 1.5 in. [*7*].

The FHWA performed a repeatability study on the MIT-SCAN2-BT and found the maximum observed variations to be as follows: repeatability = 0.08 in., horizontal and vertical alignment = 0.16 in., side shift = 0.31 in. and depth = 0.16 in. The standard deviations were reported about one third of the maximum deviations respectively [*8*].

A study completed by Prabhu et al. investigated the effect of dowel misalignment in a laboratory setting. The results showed that the load per dowel increases with larger misalignment magnitudes. The results also noted that the severity of structural distress in the form of spalling and cracking was increased for specimens with a larger number of dowels misaligned, specifically with skew or tilt, or combined misalignment (i.e., a combination of tilt, skew, and/or horizontal and vertical translation) [*9*].

OBJECTIVE

The objective of this research was to utilize the MIT-SCAN2-BT as a non-destructive dowel bar alignment measuring device to determine the effect of dowel bar alignment and its effects on JPCP. Four to eight jointed concrete pavements of each of the following ages were measured: 0-10 years, 10-20, years, and 20+ years of age to determine the effects of dowel bar misalignment on pavement performance indicators such as faulting, load transfer, and ride quality.

SCOPE

To meet the objectives of this project, eight JPCP were evaluated in the 0-10-year age range, five JPCP were evaluated in the 10-20-year age range, and four JPCP were evaluated in the 20+ year age range to determine the effects of dowel bar misalignment on pavement performance indicators such as faulting, load transfer, and ride quality. For each project, about five percent of the joints were tested, (about 15 joints per mile). The joints were tested in groups of five at 0.3-, 0.3-, and 0.4-mile increments. Additionally, every joint on the newly constructed I-49 corridor from LA1 to the Arkansas state line was measured.

METHODOLOGY

MIT-SCAN2-BT Test Method

The MIT-SCAN2-BT test method consists of placing the fiberglass track on the pavement and centering it over the joint using the marked track center. The MIT-SCAN2-BT is then pulled at an even pace over the length of the track recording the location of each dowel bar. The device then sends the data via a wireless Bluetooth connection to a handheld computer where an image of the dowel bar locations can be minimally processed and viewed. The file is named and stored for future processing. The field files are then transferred to a desktop computer upon returning to the office and processed further to better identify potential misalignment.

Field Projects

I-49 Corridor

The recently constructed sections, Sections A-I, of the I-49 corridor were evaluated. Section H was completed by LTRC personnel, while the remaining sections testing was completed by Global Pavement Solutions, Inc. Figure 3 shows the location of the project sections. Note that nearly 31 miles of interstate pavement joints were tested, actual 62 miles of JPC. For these projects, the MIT-SCAN2-BT testing was conducted on the full pavement width excluding the shoulders.

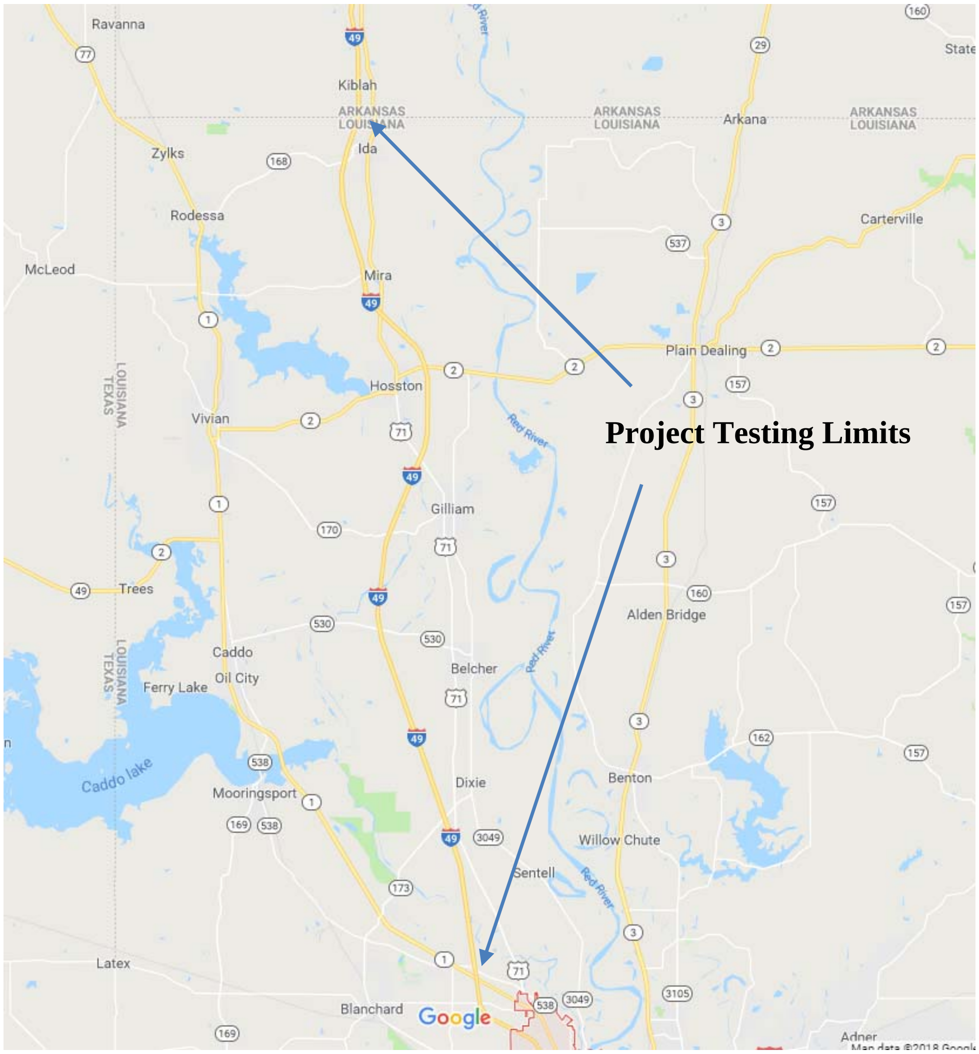

Figure 3
Location of I-49 projects

0-10 Year Projects

The 0-10-year-old projects tested consisted of projects completed as part of the Transportation Infrastructure Model for Economic Development (TIMED) program. Table 1 shows the projects tested along with the average daily traffic (ADT) and percent trucks. These projects were tested while under traffic. Testing was generally completed full width, but if traffic conditions did not allow, testing was completed on the outside lane only. The ages of these projects ranged from 1.06 to 3.41 years at the time of testing.

Table 1
0-10-year-old projects

Project	Route	District	Parish	Length (mi.)	ADT	%Trucks
023-11-0027	US 167	5	Union	7.206	3366	16
023-06-0044	US 167	5	Jackson	6.051	8000	16
023-10-0036	US 167	5	Lincoln	2.913	3420	16
023-05-0029	US 167	8	Winn	7.06	4643	16
038-03-0022	US 425	5	Morehouse	5.9	6014	16
025-02-0030	US 171	8	Sabine	6.59	5924	16
019-04-0037	US 61	61	W Feliciana	1.729	11,989	16
019-04-0036	US 61	61	W Feliciana	4.689	11,989	16

10-20-Year Projects

The 10-20-year-old projects tested consisted of projects tested are shown in Table 2. These projects were also tested while under traffic. Testing was generally completed full width, but if traffic conditions did not allow, testing was completed on the outside lane only. In the case of the I-10 project, testing was completed on the inside two lanes. The ages of these projects ranged from 12.97 to 18.11 years at the time of testing.

Table 2
10-20-year-old projects

Project	Route	District	Parish	Length (mi.)	ADT	%Trucks
810-30-0002	LA 3186	7	Calcasieu	2.05	16,455	16
450-91-0077	I-10	7	Calcasieu	4.49	54,118	17
810-19-0016	LA 108	7	Calcasieu	1.23	18,777	15
102-01-0029	LA 511	4	Caddo	1.69	2872	16
062-03-0007	LA 23	2	Plaquemines	5.74	6512	12

20+ Year Projects

The 20+-year-old projects tested consisted of projects tested are shown in Table 3. These projects were also tested while under traffic. Testing was generally completed full width, but if traffic conditions did not allow, testing was completed on the outside lane only. The ages of these projects ranged from 21.16 to 30.34 years at the time of testing.

Table 3
20+ year-old projects

Project	Route	District	Parish	Length (mi.)	ADT	%Trucks
810-12-0029	LA 378	7	Calcasieu	3.17	21,372	15
102-01-0022	LA 511	4	Caddo	1.53	4574	16
265-02-0009	LA 44	61	Ascension	1.68	10,102	16
258-31-0007	LA 42	61	E.B. Rouge	2.82	21,620	16

DISCUSSION OF RESULTS

MIT-SCAN2-BT Scans

The MIT-SCAN2-BT statewide scanning results showed that JPCP are usually built well with adequately performing joints. The results showed that all but about five projects tested were constructed using a dowel bar inserter (DBI). Of the five tested, four utilized dowel baskets and the remainder was constructed using star lugs.

The MIT-SCAN2-BT results can be displayed in several formats, including numerical and contour plots. The numerical-based results give an indication of the relative x, y, and z position of each individual bar measured within the joint. The contour plots provide a graphical representation of the numerical results. The contour plots are extremely useful in interpreting the numerical results and can show several things readily. For instance, the contour plots can show definitively which method was used for placing dowel bars during construction. The contour plots in Figure 4 and Figure 5 show joints constructed using a DBI and basket, respectively. Note the red area in the figures indicate individual bars. The darker shade of red for the basket placed dowels is due to the interference associated with the metal wire basket constructed to hold the dowel bars.

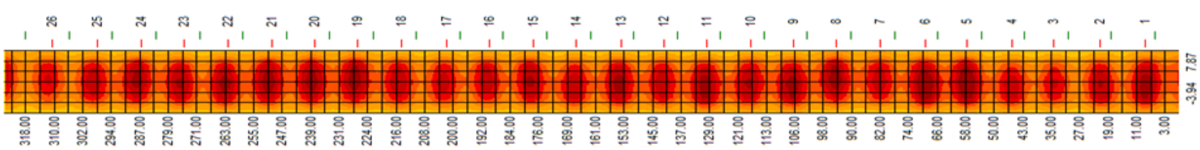

Figure 4
Contour plot for JPCP joint constructed using a DBI

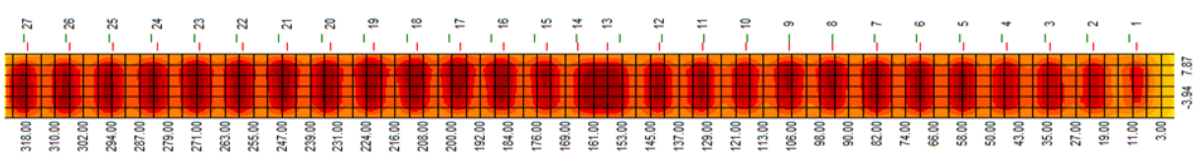

Figure 5
Contour plot for JPCP joint constructed using baskets

Several contours showed improper saw cutting, shifter or rolled baskets, missing bars, and single bars misaligned. Figure 6 shows a rare instance of a shifted or rolled dowel basket.

An example of a misaligned (longitudinally translated) and a skewed saw cut are shown in Figure 7 and Figure 8, respectively. Note with the misaligned and skewed saw cut, the contractor sawed the joint straight, but missed the middle of the dowel bars for some or all of the dowels. The misaligned saw cut is the widest instance of error for construction of joints for this study considering many of the other types of contour plots were encountered one to three times over the course of the study.

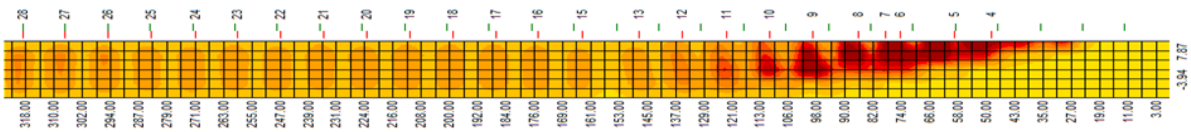

Figure 6

Contour plot exhibiting a shifted or rolled dowel basket

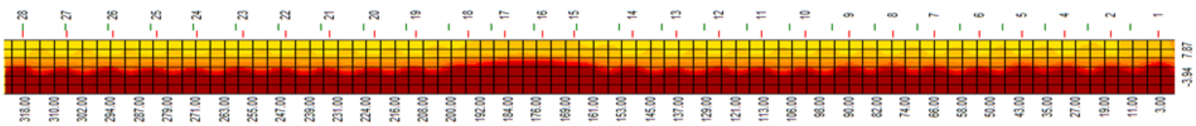

Figure 7

Contour plot exhibiting a misaligned (longitudinally translated) sawcut

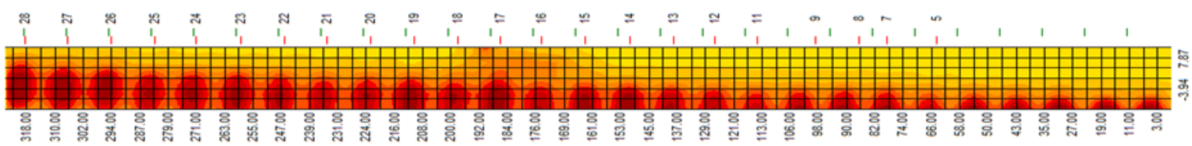

Figure 8

Contour plot exhibiting a skewed sawcut

Other issues the results were able to show included both missing dowels and single bars being misaligned. In these rare cases, the misalignment is most likely due to a malfunction in the DBI (missing dowel) or a poor concrete mixture design allowing slight movement or settlement of the dowels upon completion of the DBI process. Figure 9 shows a good joint with the third dowel from the right missing. Figure 10 shows joints with misalignment of individual bars that may be attributed to a poor concrete mixture or a malfunctioning DBI.

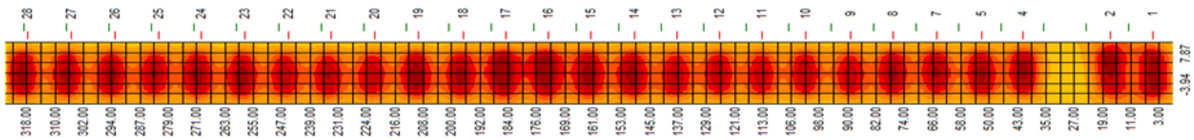

Figure 9
Contour plot exhibiting missing dowel bar

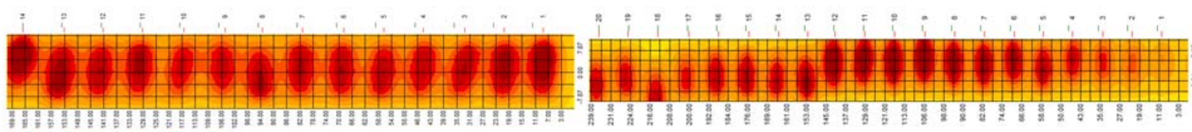

Figure 10
Contour plots exhibiting single misaligned bars

The MIT-SCAN2-BT testing brought forth some key observations for the authors. First, when testing at full pavement width, the fiberglass track is extremely flexible and fragile. LTRC had to purchase an additional track and repair both significantly to continue testing operations. Figure 11 shows some of the repairs that had to be made to the track.

In general, the equipment is accurate and a testing rate of 32-45 joints per hour can be expected for full width applications under a closed road condition. The authors noted that the pavement must be very clean or the bottom of the machine will be scratched and the results less accurate. Also, if the pavement is to be outfitted with raised pavement parkers, it is best to conduct all MIT-SCAN2-BT testing prior to the placement of said raised pavement markers.

Figure 11
Examples of epoxy repair to the fiberglass track

I-49 Corridor

The I-49 corridor is the most tested corridor in the world using the MTI-SCAN2-BT technology. Over 35,000 individual joints were tested over a two-month period. Note that all joints were tested and expansion joints were then manually removed from the data set since they contain no dowel bars.

Figure 12 shows the results for the I-49 corridor by individual sections. The results showed overwhelmingly that vertical tilt, horizontal skew, vertical translation, and horizontal translation are not an issue for constructed JPCP joints within the corridor. Longitudinal translation was the most commonly observed type of misalignment. Longitudinal translation generally occurs when the joints are marked and sawn in an incorrect location relative to the installed dowel bars or dowel baskets. A slight bit of longitudinal translation is expected from the midpoint of the bar due to the difficulty in marking and locating dowels exactly and precisely sawing said joint. Note that although longitudinal translation may exist, it will only be detrimental when subjected to significant truck loading.

The results showed that Section B was built with dowel baskets while the remaining sections were built using a DBI. Section B also had the one instance of a rolled, or shoved basket. This can occur if the basket is not properly attached to the subgrade or if the basket is caught on a piece of equipment in the paving train.

Section D was the section that caused the most concern for the Department and led to the creation of this research effort. Note that although longitudinal translation does occur, with the exception of Sections D an H, the number of joints with dowels with less than 4 in. of embedment is less than 5 percent of the project joints. Past literature reviewing longitudinal dowel misalignment on an interstate section indicates that as little as 2.5 in. is needed for sufficient load transfer [*5*]. Upon completion of the I-49 testing, LTRC personnel continued testing older pavement sections to determine the effect of longitudinal translation on long-term JPCP performance.

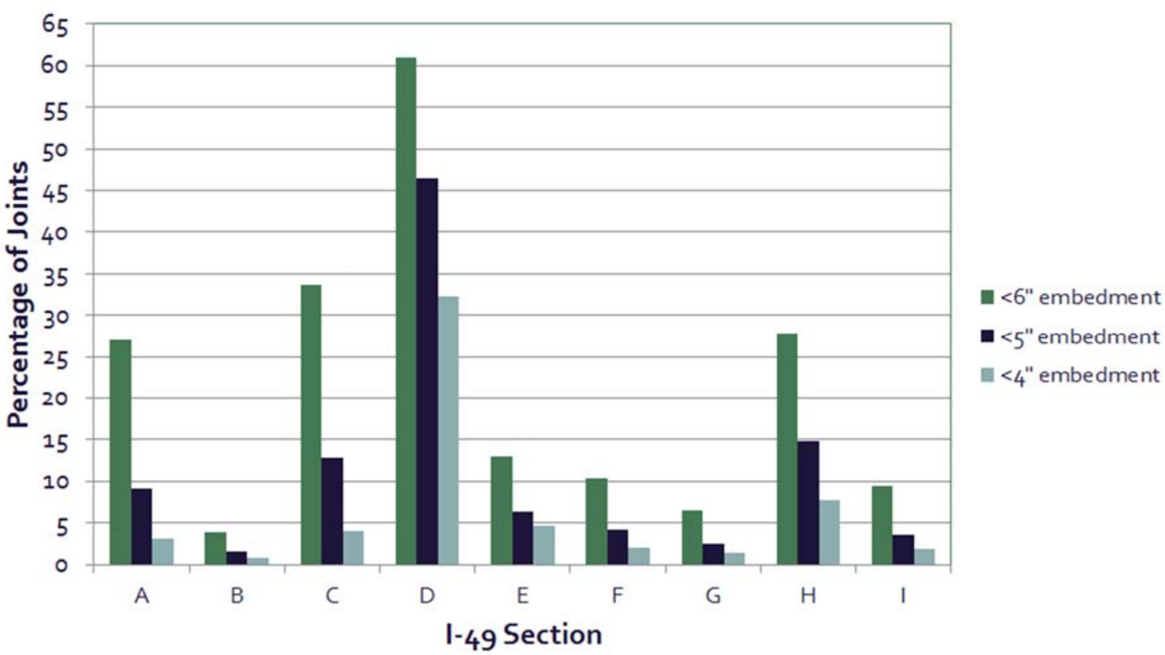

Figure 12
Percentage of joints on the I-49 corridor with measured embedment lengths less than 6, 5, and 4 in.

0-10-Year-Old Pavements

Figure 13 shows the results for the 0- to-10-year-old JPCP sections. The results show that for two pavement sections, no measurable longitudinal translation was found among tested joints. Granted, only 5 percent of the joints were measured, but this is a remarkable feat for any construction operation. The remaining sections had between 0 and 15 percent of the joints with dowels less than 4 in. of embedment.

Although the 019-04 project results showed 15 percent of the joints tested with less than 4 in. of embedment, LTRC field testing personnel found it very difficult to find any measurable faulting at the joint. With faulting being the major distress occurring with short embedment lengths, the authors believe that the embedment lengths of 4 in. are sufficient for long term load transfer. LTRC personnel will continue to observe the 019-04 projects to determine if any faulting issues arise with the number of dowel bars with less than 4 in. of embedment.

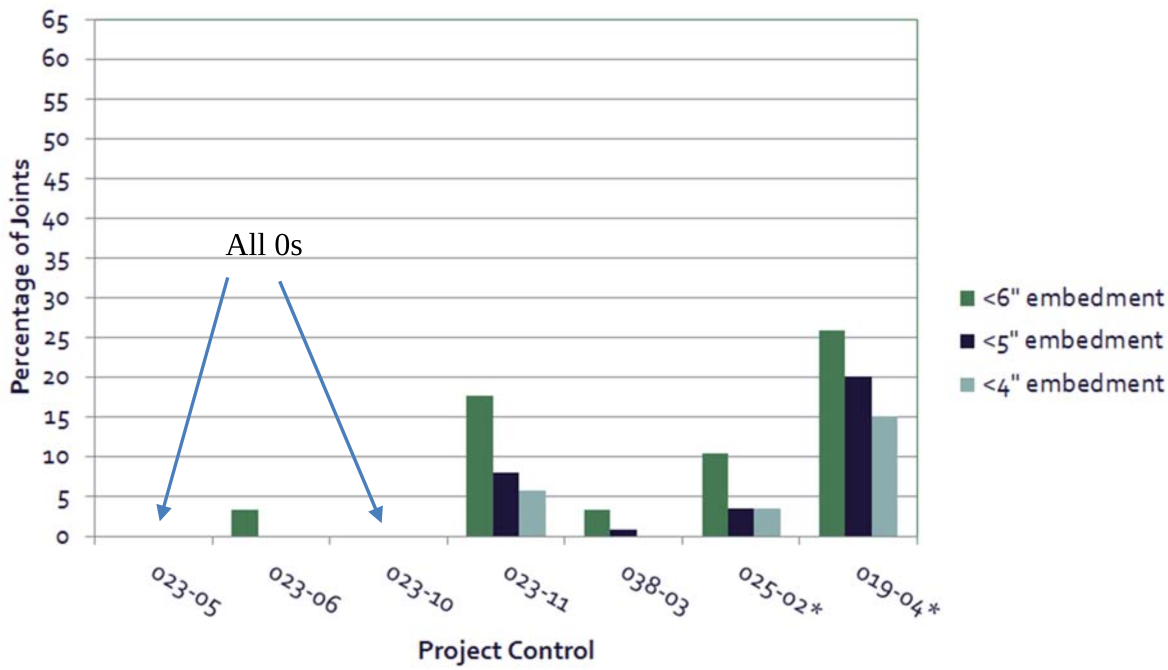

Figure 13
Percentage of joints in pavements 0-10-years old with measured embedment lengths less than 6, 5, and 4 in. (*outside lane measured only)

10-20-Year-Old Pavements

Figure 14 shows the results for the 10- to-20-year-old JPCP sections. The results show that, in general, these projects were constructed well with many joints having embedment lengths exceeding 5 in. The 102-01 project showed that nearly 40 percent of the joints measured have dowels with an embedment length less than 4 in.

The 450-91 project showed about 2.5 percent of the joints measured to be constructed with dowels less than 5 in. of embedment. With the high ADT and large percent trucks in this interstate section, one would expect to see faulting is the embedment length was an issue. In this field project, faulting was manually measured to be less than 1/16 in.

Although the 102-01 project results showed 40 percent of the joints with less than 4 in. of embedment, LTRC field testing personnel found it very difficult to find any measurable faulting at the measured joints. This may be due to the low volume nature of the roadway with an ADT of about 2900. The traffic spectra measure 16 percent trucks, and, at an age of over 15 years, if the embedment length were to cause an issue such as faulting, DOTD personnel would have measured it by now.

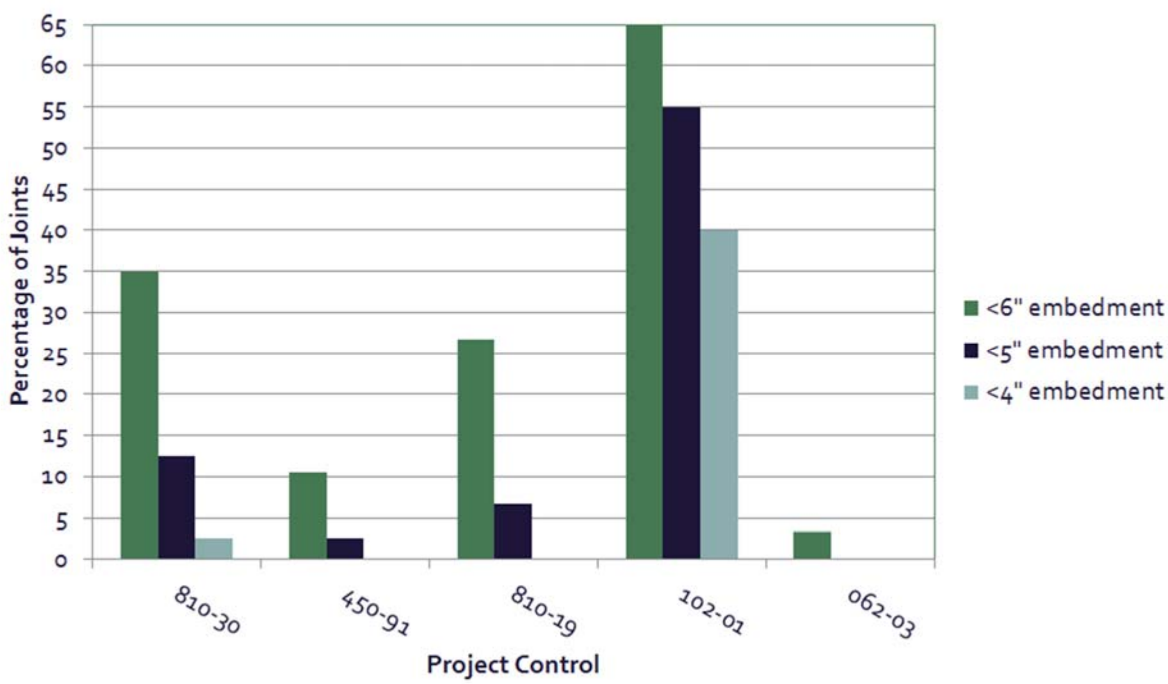

Figure 14
Percentage of joints in pavements 10-20-years-old with measured embedment lengths less than 6, 5, and 4 in.

20+ Year-Old Pavements

Figure 15 shows the results for the 20+ year-old JPCP sections. The 258-31 project shows the joints being constructed such that no measurable translation can be determined. That being said, the pavement exhibits no faulting at the joints, but the slab condition is significantly deteriorated, most likely due to poor subgrade support conditions.

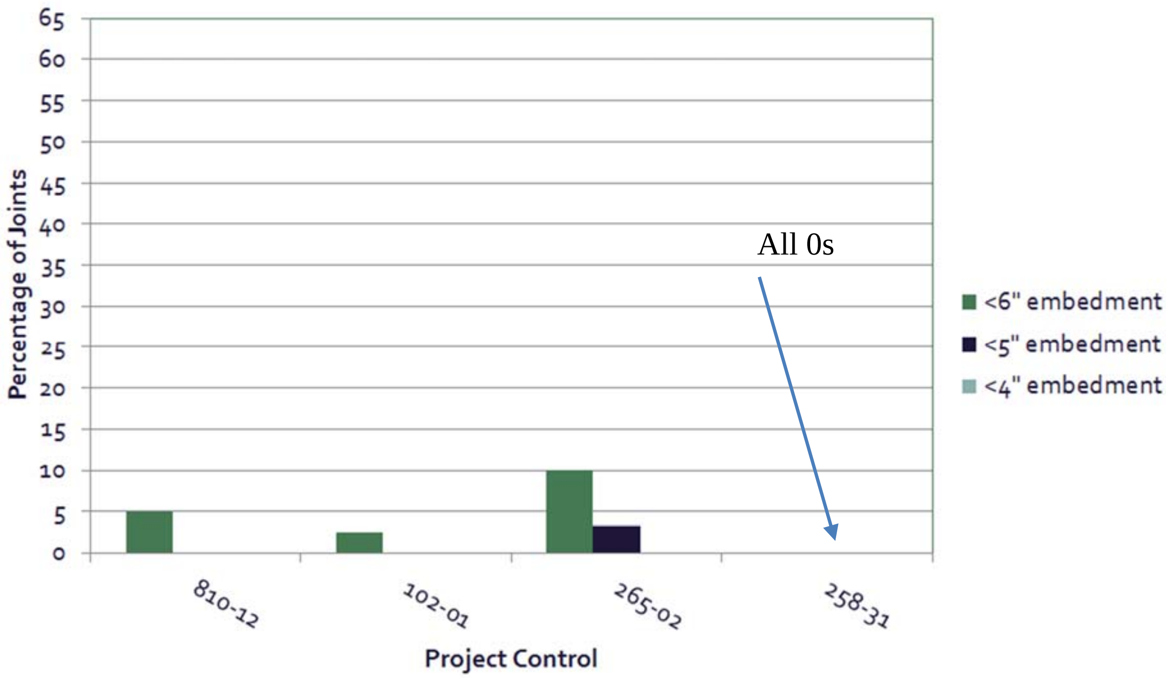

Figure 15
Percentage of joints in pavements 20+ years-old with measured embedment lengths less than 6, 5, and 4 in.

The 810-12 project showed significant faulting, as well as mid-panel cracking. The results were further analyzed and the contour map images shown in Figure 16 showed an "abnormal" dowel. Investigation by the authors uncovered that this pavement section was constructed using star lugs. Figure 17 and Figure 18 show magnitude of the faulting, in once case exceeding ¼ in.

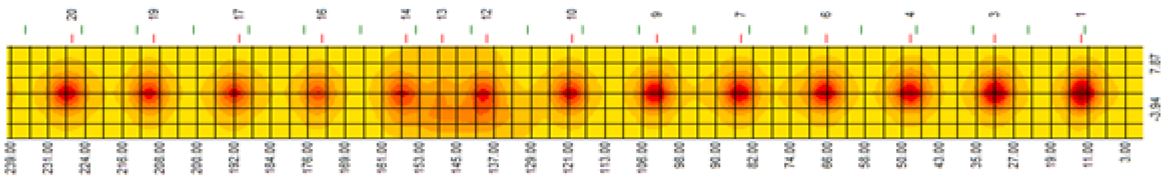

Figure 16

Contour plot result for star lug load transfer devices

Figure 17

Faulting of adjacent pavement slabs for the 810-12 project slightly less than ¼ in.

Figure 18

Faulting of adjacent pavement slabs for the 810-12 project exceeding ¼ in.

The MIT-SCAN2-BT results of the older age pavements, measured embedment lengths less than 4 in. and some measured between 2.5 and 3 in., lend positive support to the Minnesota study results indicating that an embedment length of 2.5 in. may be sufficient for adequate load transfer and prevention of faulting. While embedment length may not be an issue in the pavement studies, the authors are quick to note that load transfer is not alone supported by dowel bars. The subgrade, subbase, and other related items within the pavement structure do assist with proper load transfer. The results show that the Department's current dowel placement specifications lead to acceptable long-term joint performance.

CONCLUSIONS

The MIT-SCAN2-BT device is accurate, but the flexible track is fragile and will need repairs in extended testing scenarios. Testing rates range from 32-45 joints per hour for full width pavement sections in a closed road condition. The pavement surface must be free of debris and measurements should be conducted prior to application of raised pavement markers.

Pavements constructed over the past 30 years that contain dowel bars in the joint detail are performing well with regards to measurable faulting. Measured joints were constructed with no horizontal skew, vertical translation, vertical tilt, or horizontal translation. The results indicated that the pavement sections should not exhibit joint lock due to dowel skew or tilt.

The MIT-SCAN2-BT device is very capable of locating and measuring dowel bars and assemblies. It is also capable of determined whether or not a bar is missing, or if the load transfer device is something other than a dowel bar. The results also indicate that the effect of longitudinally translated dowel bars is negligible. Acceptable long-term performance was observed in joints with less than 4 in. of embedment and some joints with 2.5 to 3 in. of embedment. The Department’s current dowel placement specifications lead to acceptable long-term joint performance.

RECOMMENDATIONS

In general, concerning longitudinal translation, a dowel bar embedment length of 4 in. is sufficient to provide load transfer, with several joints exhibiting good performance at 15+ years of age with 2.5 to 3 in. of embedment. The authors do not recommend implementing the use of the MIT-SCAN-BT for quality control or quality assurance purposes due to the findings of this study. The authors do not recommend changing the current dowel placement specifications.

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ADT	average daily traffic
CPTP	Concrete Pavement Technology Program
DOTD	Louisiana Department of Transportation and Development
FHWA	Federal Highway Administration
in.	inch(s)
JPCP	jointed plain concrete pavement
LTRC	Louisiana Transportation Research Center
mi.	mile(s)
QA	quality assurance
TIMED	Transportation Infrastructure Model for Economic Development

REFERENCES

1. Khazanovich, L. and Hoegh, K., *Guidelines for Dowel Alignment in Concrete Pavements.* NCHRP Report 637, TRB, Washington D.C., 2009.
2. Leong, B. "Joint Design and Joint Performance of Plain Concrete Pavements (JPCP) – Investigations and Experiences in Germany." Proceedings, 8th International Conference on Concrete Pavements, Colorado Springs, CO, 2005.
3. Odden, T. R., Snyder, M., and Schultz, A. *Performance Testing of Experimental Dowel Bar Retrofit Designs: Part I – Initial Testing.* Final Report. Minnesota Department of Transportation, Minneapolis, MN, 2003.
4. Fowler, G. and Gulden, W. *Investigation of Location of Dowel Bars Placed by Mechanical Implantation*. Georgia Department of Transportation, Report No. FHWA/RD-82/153. Federal Highway Administration, Washington, D.C., 1983. http://www.forconstructionpros.com/article/11301558/internal-curing-holds-water
5. Burnham, T., *A Field Study of PCC Joint Misalignment Near Fergus Falls, Minnesota*, MnDOT, St. Paul, MN, 1999.
6. "Best Practices for Dowel Placement Tolerances" CPTP Tech Brief, FHWA, 2007.
7. "Dowel Bar Alignment and Location for Placement by Mechanical Dowel Bar Insertion" ACPA Guide Specifications, http://acpa.org/downloads/13_1_7%20-%20ACPA%20Dowel%20Alignment%20Guide% 20Spec.pdf, 2013.
8. Yu, T. and Khazanovich, L., *Use of Magnetic Tomography Technology to Evaluate Dowel Placement*. Report FHWA-IF-06-006, FHWA, 2005.
9. Prabhu, M., Buch, N., Varma, A., and Thandaveswara, D. "Experimental Investigation of the Effects of Dowel Misalignment on Joint Opening Behavior in Rigid Pavements." *Transportation Research Record: Journal of the Transportation Research Board, No. 1947*, Transportation Research Board of the National Academies, Washington, D.C., 2006, pp. 15-27.

This public document is published at a total cost of $250
42 copies of this public document were published in this first printing at a cost of $250. The total cost of all printings of this document including reprints is $250. This document was published by Louisiana Transportation Research Center to report and publish research findings as required in R.S. 48:105. This material was duplicated in accordance with standards for printing by state agencies established pursuant to R.S. 43:31. Printing of this material was purchased in accordance with the provisions of Title 43 of the Louisiana Revised Statutes.