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Dowel Bar Size and Spacing for Rigid Pavements

Prepared for
WHRP Rigid Pavements
Technical Oversight Committee

Prepared by
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WisDOT Research & Library Unit

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Topic/Problem Statement: We were asked to identify research on dowel bar sizes and spacing for load transfer between portland cement concrete pavement slabs. The TOC was particularly interested in research on dowels of 1-inch (25 mm) diameter or less in 10- or 12-inch-thick concrete pavement layers, and in research on selective or preferential spacing.

Keywords: Dowel, size, spacing, diameter, preferential, placement, wheel, path.

Summary

We found 18 publications from 2001 through 2006 addressing dowel bar design. Many specifically speak to bar size and spacing of bars across joints, though in almost every case a focus on materials—steel, fiber-reinforced polymer, or cement-filled, for example—is central. Dowel bar sizes in the cited research include 1-inch and ¾-inch (25 mm and 19 mm, respectively); spacing options include preferential distribution in wheel paths of select lanes, or spacing varying from 8 to 15 inches. In most cases small bar sizes and spacing were not evaluated simultaneously, so spacing variation was typically evaluated in situations employing 1.5-inch or larger dowels.

Of the 18 citations below, we found four articles and reports published in 2006, 2005 and 2003, three in 2001, two in 2002, and one in 2004. Of these, four were academic articles or theses, six were conference papers, six were published by TRB or another national transportation agency, and two were state publications from Kansas and Iowa (both in 2003).

One research project is ongoing, an investigation of elliptically shaped steel dowels by James Cable at Iowa State University, who has also been involved with research on elliptical FRP dowels and other dowel configurations. The cited study is expected to conclude in 2008.

Citations

Results are listed chronologically within each category, with the most recent citations first. Links to online copies of cited literature are provided when available. Contact the WisDOT Library to obtain hard copies of citations.

Title: Field Evaluation of Elliptical Steel Dowel Performance (Interim Report)
Author(s): James K. Cable, Stacia L. Totman, Nathan Pierson
Date: December 2006
Doc ID/URL: FHWA Project DTFH6103C00119. http://www.ctre.iastate.edu/reports/elliptical_steel_interim.pdf
Description: 304 pp.
Contents: Joints are always a concern in the construction and long-term performance of concrete pavements. Research has shown that we need some type of positive load transfer across transverse joints. The same research has directed pavement designers to use round dowels spaced at regular intervals across the transverse joint to distribute the vehicle loads both longitudinally and transversely across the joint. The goal is to reduce bearing stresses on the dowels and the two pavement slab edges and erosion of the underlying surface, hence improved long-term joint and pavement structure performance. Road salts cause metal corrosion in doweled joints, excessive bearing stresses hollow dowel ends, and construction processes are associated with cracking pavement at the end of dowels. Dowels are also a cost factor in the pavement costs when joint spacing is reduced to control curling and warping distress in pavements. Designers desire to place adequate numbers of dowels spaced at the proper locations to handle the anticipated loads and bearing stresses for the design life of the pavement. This interim report is the second of three reports on the evaluation of elliptical steel dowels. This report consists of an update on the testing and performance of the various shapes and sizes of dowels. It also documents the results of the first series of performance surveys and draws interim conclusions about the performance of various bar shapes, sizes, spacings, and basket configurations. In addition to the study of elliptical steel dowel performance, fiber reinforced polymers (FRP) are also tested as elliptical dowel material (in contrast to steel) on a section of the highway construction north of the elliptical steel test sections.

Title: Assessment of grouted Glass Fibre-Reinforced Polymer (GFRP) tubes as dowel bar alternatives
Author(s): Duan-Yi Wang, Chi-Chun Hu, Richard Robert
Date: 2006
Doc ID/URL: *25th Annual Southern African Transport Conference, SATC 2006-2010: Will Transport Infrastructure and Systems Be Ready*, 2006: 54-63.
Description: 10 pp.
Contents: The vast majority of highways and roads in China are made of jointed concrete pavement. The performance of concrete pavements depends to a large extent on the satisfactory performance of the joints. At present, the load-transfer devices used in China are almost all steel dowel bars. The new Chinese specification further emphasises the importance of dowels by stipulating that dowel bars be set in all highway jointed concrete pavements, increasing the diameter requirement and lowering the bar spacing, so the demand for steel is greatly increased. Currently, steel prices are increasing. With the international ironstone price rising by 70% last year, steel prices in China are likely to rise much higher, and the cost of civil engineering works using steel will also increase accordingly. Besides, steel dowel bars are susceptible to erosive agents. Moreover, the concentration of stresses occurs at the interfaces between the dowels and the supporting concrete because the stiffness of the steel is too great. Therefore, it is necessary to seek a substitute for steel dowel bars. Four grouted glass fibre-reinforced polymer (GFRP) tube dowels were compared with conventional steel dowel bars by means of laboratory experiments, theoretical analysis and finite element analysis. The research results revealed that grouted wound GFRP tube was a feasible substitute which could solve the problems posed by the currently used steel dowel bars, such as corrosion, excessive bearing stress and high cost. Finally, recommendations for further research on dowel bar alternatives are given. (13 refs.)

Title: Influence of Selected Design and Construction Features on JPCP Performance
Author(s): Taslima Khanum, Mustaque Hossain, Richard Barezinsky, Stefan Romanoschi
Date: 2006
Doc ID/URL: *Transportation Research Board 85th Annual Meeting*, 2006. Paper No. 06-2926.
Description: 21 pp.
Contents: Site conditions, pavement design features, and construction practices are all known to influence the long-term performance of Jointed Plain Concrete Pavements (JPCP). The traditional empirical design procedures for JPCP were unable to take into account most of these factors. However, a new pavement design procedure, developed by the National Cooperative Highway Research Program (NCHRP) and now known as the Mechanistic-Empirical Pavement Design Guide (MEPDG), accounts for climatic conditions, local materials, selected construction practices, and actual highway traffic distribution. In this study, the performance of six typical JPCP

pavements in Kansas due to alternative inputs corresponding to widened lane, shoulder type (tied vs. untied), dowel diameter, dowel spacing, base type (stabilized and granular), and curing method (curing compound vs. wet curing) was evaluated using NCHRP MEPDG. The results show that predicted JPCP roughness (IRI) by MEPDG is very sensitive to varying dowel diameter. Lower dowel diameter results in higher JPCP faulting. However, variation in dowel diameter does not affect predicted slab cracking. Predicted roughness, faulting, and slab cracking of JPCP pavements are significantly reduced by tied concrete shoulder. No faulting was observed for a JPCP with a widened lane that also had tied concrete shoulder. Lower roughness and lesser cracking were also obtained for the widened lane. There are no marked differences in performance with respect to the treated base types. No significant effect on IRI, faulting, and slab cracking was observed for dowel spacing from 10 to 14 inches (250 to 350 mm). Effect of curing method on the predicted JPCP distresses was not very prominent.

Title: Evaluation of Jointed Plain Concrete Pavement with Fiber-Reinforced Polymer Dowels
Author(s): P.V. Vijay, GangaRao V.S. Hota, Hui Li
Date: 2006
Doc ID/URL: *Transportation Research Board 85th Annual Meeting*, 2006. Paper No. 06-2112.
Description: 17 pp.
Contents: In this study, Fiber Reinforced Polymer (FRP) dowel bars were evaluated as load transferring devices for JPCP in laboratory and field under HS-25 equivalent static and fatigue loads and compared their response with JPCP consisting of steel dowels. Analytical modeling of dowel response was carried out in terms of maximum bending deflection, relative deflection, and bearing stress for different parameters such as dowel diameter, spacing, dowel material properties, joint width, and base material properties. Rehabilitation of an existing concrete pavement was carried out using FRP dowels. Both 1.5" and 1.0" diameter FRP dowels were installed in the field with 6", 8", 9" and 12" spacings. Field data collected through automatic data acquisition system included dowel strains and joint deflections, which were used for assessing joint load transfer efficiency (LTE), relative deflection, and pavement performance. This research shows that JPCP with FRP dowels provide very good LTE up to and beyond 90%, which exceeds AASHTO recommendation of 70%. JPCP with FRP dowels provided sufficient LTE after 5 million cycles of fatigue loading under HS-25 loading. FRP dowels were found to require less length than steel dowels for force transfer. Though theoretical peak bearing stress on concrete slab for FRP dowels is higher than steel dowels, average bearing stress values were found to be significantly lower. Good interface between FRP dowels and concrete was found near the joints where peak bearing stresses are present. Field installed FRP JPCP subjected to heavy traffic loading is performing very satisfactorily after four years of installation.

Title: A laboratory investigation on bonding properties of dowels in concrete roads
Author(s): M. Lofsjogard
Date: August/September 2005
Doc ID/URL: *Materials and Structures*, Vol. 38 (281), August/September 2005: 721-728.
Description: 8 pp.
Contents: Inclined dowel bars and immovable bars may cause pavement cracking in the vicinity to the bar ends. The aim of the investigation is to study if there are any differences in bonding properties due to dowel material, coating or diameter of the dowel. Steel dowels with different coatings and dowels made of composite material are tested. The maximum draw-out force for a draw-out travel of 1.5 mm is measured. The test is repeated four times and ends with a final cycle to establish the constant force needed for a draw-out travel of 5 mm. Steel dowels with bituminous coating show the lowest initial draw-out force. The draw-out force increased 2 to 3 times with a diameter increase of 50% for steel dowels with plastic coatings. For composite dowels the comparing result showed an increase of draw-out force 2 to 5 times with an increase in diameter with one third. The results from the repeating test for several cycles showed that the draw-out and push-back force were almost the same for all dowels. However, for the dowels with bituminous coating a higher push-back force was needed compared to the draw-out force. It should be noted that the testing speed could affect the results, especially for dowels with bitumen. (9 refs.)

Title: Field Evaluation of Elliptical Fiber Reinforced Polymer Dowel Performance
Author(s): Max Porter, James Cable, John Harrington, Nathan Pierson, Anthony Post
Date: June 2005
Doc ID/URL: DTFH61-01-X-00042, Project 5, Final Report, Iowa State Univ. http://www.ctre.iastate.edu/reports/frp_dowel.pdf. Tech Transfer Summary, http://www.ctre.iastate.edu/pubs/t2summaries/frp_dowel.pdf.
Description: 93 pp.
Contents: Fiber reinforced polymer (FRP) composite materials are making an entry into the construction market in both buildings and pavements. The application to pavements so far has come in the form of joint reinforcement (dowels and tie bars). FRP resistance to salt corrosion in dowels has made it an alternative to standard epoxy-coated

steel dowels for pavements. Iowa State University has completed a large amount of laboratory research to determine the diameter, spacing, and durability of FRP dowels. This report documents the performance of elliptical FRP dowels installed in a field situation. Ten joints were monitored in three consecutive test sections, for each of three dowel spacings (10, 12, and 15 inches) including one instrumented dowel in each test section. The modulus of dowel bar support was determined using falling weight deflectometer (FWD) testing and a loaded crawl truck. FWD testing was also used to determine load transfer efficiency across the joint. The long-term performance and durability of the concrete was also evaluated by monitoring faulting and joint opening measurements and performing visual distress surveys at each joint. This report also contains similar information for standard round, medium elliptical, and heavy elliptical steel dowels in a portion of the same highway. In addition, this report provides a summary of theoretical analysis used to evaluate joint differential deflection for the dowels.

Title: Changing the shape and location of pavement load transfer devices
Author(s): James K. Cable
Date: 2005
Doc ID/URL: *Transportation Research Record 1907*, 2005: 95-101.
Description: 7 pp.
Contents: Load transfer is an important aspect of portland cement concrete joint design. To date, aggregate interlock and round steel dowels have been used to accomplish load transfer. Research was done to examine the use of steel dowels of alternative shapes to provide load transfer. A field research project in Iowa has used two elliptical bars of different sizes at three spacings and numbers of bars per joint. Test sections included bars across the entire joint and sections using bars only in the wheelpaths. The impact of cut, fill, and transition sections was also factored into the experimental design. This paper documents the construction of the project, testing that is being done, and the initial results of the work. (1 ref.)

Title: The second generation of Minnesota accelerated loading facility: Minne-ALF-2
Author(s): Lev Khazanovich, Iliya Yut, Derek Thompkins, Arturo Schultz
Date: 2005
Doc ID/URL: *8th International Conference on Concrete Pavements*, 2005: 1013-1029.
Description: 17 pp.
Contents: This paper presents the second generation of Minnesota Accelerated Loading Facility (Minne-ALF-2), a laboratory-based loading pavement test stand that simulates the passage of heavy wheel loads moving over a small full-scale pavement test strip. It is shown that Minne-ALF-2 can provide important information related to long-term performance of dowel joints of concrete pavements, as well as useful information which may lead to a better understanding of the mechanics of joints in concrete pavements. The first results of the ongoing test program are also presented in the paper. This initial study of joint behavior during loading and unloading of a joint with hollow dowels reveals an interesting pattern: deflections in the unloading path are different from the deflections at the loading path. It was also found that the residual differential deflections remain after the first loading and unloading cycle. Available finite element models for rigid pavements do not explain these effects. Hence, advanced models of portland cement concrete (PCC) joints explaining the observed above phenomenon are needed for a better understanding of the joint behavior and joint design optimization.

Title: Mechanistic-empirical model to predict transverse joint faulting
Author(s): Lev Khazanovich, Michael Darter, H. Thomas Yu
Date: 2004
Doc ID/URL: *Transportation Research Record 1896*, 2004: 34-45
Description: 12 pp.
Contents: A summary is presented of the procedures used to model the effects of transverse joint faulting in the design of jointed plain concrete pavements v in the 2002 Design Guide, which was developed under NCHRP Project 1-37A, Development of the 2002 Guide for Design of New and Rehabilitated Pavement Structures. The mechanistic-empirical 2002 guide procedure for rigid pavement design incorporates several key features that are expected to offer significant improvements in design accuracy. The 2002 Design Guide faulting model identifies the differential energy of subgrade deformation as the mechanistic parameter governing joint faulting development. This parameter reflects total pavement flexibility and the level of load transfer efficiency. The 2002 design procedure uses the incremental damage approach. It allows for direct consideration of changes in many factors throughout the entire design period and joint load transfer, including material properties (concrete strength and modulus), seasonal climatic conditions, traffic loadings, subgrade support, and others. Each analysis increment represents a specific combination of the preceding factors over a distinct period (month, season, etc.). The main concepts are described, the model overview presented, and the results of the model calibration provided. Several examples illustrating

sensitivity of the 2002 Design Guide faulting prediction to the key design parameters (dowel diameter, slab width and edge support, built-in temperature gradient, and others) are also provided. (16 refs.)

Title: Accelerated Testing for Studying Pavement Design and Performance (FY 2001): Evaluation of the Performance of Permeable and Semi-Permeable Unbound Granular Bases Under Portland Cement Concrete Pavement (PCCP) Slabs and Alternate Load Transfer Devices for Joint Repair
Author(s): Hani Melham, Roger Swart, Sandy Walker
Date: November 2003
Doc ID/URL: FHWA-KS-02-7, Final Report, 2003. http://ntl.bts.gov/lib/24000/24600/24603/KS027_Report.pdf
Description: 89 pp.
Contents: The objectives of this research are to determine the effect of unbound drainable base types on the performance of PCCP and the efficiency of fiber-reinforced polymer (FRP) dowels, compared to epoxy coated steel dowels, when retrofitted to re-establish the load transfer in damaged non-doweled joints. The experiment was conducted at the Accelerated Testing Laboratory at Kansas State University, and consisted of constructing two pavements, one with permeable base and another with semi-permeable base, and subjecting them to full-scale accelerated pavement test. Water was periodically spread at the surface of the pavement to simulate the effect of rainfall, induce the accumulation of water in the base and to allow the comparison of the drainage capability and the performance of the two unbound bases. The measured stresses and strains as well as the distresses observed on the two pavements clearly indicated a better performance for the permeable granular base. The semi-permeable base pavement exhibited severe cracking and pumping of fines from the base and subgrade. The joints and cracks in the semi-permeable base pavement were retrofitted with 1.5 inch FRP dowels and one inch steel dowels to re-establish the shear transfer. After an additional 25,000 passes were applied to the repaired pavement it was observed that the conventional steel dowels give a better performance than the FRP dowels.

Title: Demonstration and Field Evaluation of Alternative Portland Cement Concrete Pavement Reinforcement Materials
Author(s): J.K. Cable, M.L. Porter
Date: June 2003
Doc ID/URL: HR-1069, Final Report. NTIS, Contract No. DTFH71-97-TE030-IA-48.
Description: 72 pp.
Contents: Transverse joints are placed in portland cement concrete pavements to control the development of random cracking due to stresses induced by moisture and thermal gradients and restrained slab movement. These joints are strengthened through the use of load transfer devices, typically dowel bars, designed to transfer load across the joint from one pavement slab to the next. Epoxy coated steel bars are the materials of choice at the present time, but have experienced some difficulties with resistance to corrosion from deicing salts. The research project investigated the use of alternative materials, dowel size and spacing to determine the benefits and limitations of each material. In this project two types of fiber composite materials, stainless steel solid dowels and epoxy coated dowels were tested for five years in side by side installation in a portion of U.S. 65 near Des Moines, Iowa, between 1997 and 2002. The work was directed at analyzing the load transfer characteristics of 8-in. vs. 12-in. spacing of the dowels and the alternative dowel materials, fiber composite (1.5- and 1.88-in. diameter) and stainless steel (1.5-in. diameter), compared to typical 1.5-in. diameter epoxy-coated steel dowels placed on 12-in. spacing. Data were collected biannually within each series of joints and variables in terms of load transfer in each lane (outer wheel path), visual distress, joint openings, and faulting in each wheel path. After five years of performance the following observations were made from the data collected. Each of the dowel materials is performing equally in terms of load transfer, joint movement and faulting. Stainless steel dowels are providing load transfer performance equal to or greater than epoxy-coated steel dowels at the end of five years. Fiber reinforced polymer (FRP) dowels of the sizes and materials tested should be spaced no greater than 8 in. apart to achieve comparable performance to epoxy coated dowels. No evidence of deterioration due to road salts was identified on any of the products tested. The relatively high cost of stainless steel solid and FRP dowels was a limitation at the time of this study conclusion. Work is continuing with the subject materials in laboratory studies to determine the proper shape, spacing, chemical composition and testing specification to make the FRP and stainless (clad or solid) dowels a viable alternative joint load transfer material for long lasting portland cement concrete pavements.

Title: Field Evaluation of Alternative Load Transfer Device Locations in Low Traffic Volume Pavements
Author(s): J.K. Cable, S.J. Somsky, L.E. Edgar
Date: 2003
Doc ID/URL: TR-420, Iowa Department of Transportation, Final Report.
http://www.operationsresearch.dot.state.ia.us/reports/reports_pdf/hr_and_tr/reports/tr420.pdf
Description: 132 pp.
Contents: In jointed portland cement concrete pavements, dowel bars are typically used to transfer loads between adjacent slabs. A common practice is for designers to lace dowel bars at a certain, consistent spacing such that a sufficient number of dowels are available to effectively transfer anticipated loads. In many cases, however, the standards developed today for new highway construction simply do not reflect the design needs of low traffic volume, rural roads. The objective of this research was to evaluate the impact of the number of dowel bars and dowel location on joint performance and ultimately on pavement performance. For this research, test sections were designed, constructed, and tested in actual field service pavement. Test sections were developed to include areas with load transfer assemblies having three and four dowels in the outer wheel path only, areas with no joint reinforcement whatsoever, and full lane dowel basket assemblies as the control. Two adjacent paving projects provided both rural and urban settings and differing base materials. This report documents the approach to implementing the study and provides discussion and suggestions based on the results of the research. The research results indicate that the use of single three or four dowel basket assemblies in the outer wheel path is acceptable for use in low truck volume roads. In the case of roadways with relatively stiff bases such as asphalt treated or stabilized bases, the use of the three dowel bar pattern in the outside wheel path is expected to provide adequate performance over the design life of the pavement. In the case of untreated or granular bases, the results indicate that the use of the three or four dowel bar basket in both wheel paths provides the best long-term solution to load transfer and faulting measurements.

Title: Joint-load shear transfer testing of steel fibre reinforced concrete slabs on ground
Author(s): P.H. Bischoff, A. Cameron, S. Deschenes
Date: 2003
Doc ID/URL: *CSCE 31st Annual Conference Proceedings: 2003 Building Our Civilization – 5th Construction Specialty Conference, 8th Environmental and Sustainable Engineering Specialty Conference and Offshore Engineering Specialty Conference*, 2003: 1370-1377.
Description: 8 pp.
Contents: Providing adequate shear load transfer across cracked joints is an important design criterion that affects long-term serviceability requirements of ground supported slabs and pavements. Load transfer across steel fibre reinforced concrete (SFRC) joints is investigated for 150 mm thick slab strips cast on a polystyrene subgrade. Behaviour is compared with plain concrete joints and plain concrete joints reinforced with a 19 mm diameter steel dowel bar. Results indicate that the SFRC joint has a load transfer effectiveness of about 90% that is comparable to a dowelled joint. Joint load transfer of the plain concrete joints tested was as low as 45% and was affected by the crack width opening. Loading was monotonic, and cyclic load testing is required to obtain a more realistic evaluation of joint effectiveness under repeated loading. (6 refs.)

Title: Modelling of concrete pavement dowel-slab interaction
Author(s): Scott Murison, Ahmed Shalaby, Aftab Mufti
Date: June 2002
Source/URL: *CSCE 30th Annual Conference Proceedings: 2002 Challenges Ahead, 4th Structural Specialty Conference, 4th Transportation Specialty Conference and 2nd Material Specialty Conference*, 2002: 2621-2630.
Description: 10 pp.
Contents: In this study, the interaction between a dowel and the concrete slab of a transverse pavement joint are modeled using a finite element analysis tool. The model is designed to investigate the deflection of a dowel bar under traffic loading and the bearing stresses that are produced at the dowel-concrete interface. High bearing stresses can damage the concrete encasing the dowel leading to dowel-looseness and eventual slab-faulting. Non-corrosive materials such as fibre-reinforced polymer (FRP) have been introduced as alternative dowel materials. FRP exhibits lower flexural stiffness than typical epoxy-coated steel dowels, but has been shown to transfer traffic loads across the joint adequately. FRP has provided excellent performance in pavements thus far, but the long-term performance is unknown. This study utilizes the finite element approach to investigate the behavioural differences between steel and lower-strength FRP dowels under load. Two diameter sizes of each material were modeled in order to determine the effect of dowel diameter on deflections and bearing stresses. Results from the finite element model were compared with widely accepted theoretical solutions and it was found that correlation between the two was sensitive to an elastic parameter known as the modulus of dowel support. (16 refs.)

Title: Evaluation of Fiber Composite and Stainless Steel as Alternative Dowel Bar Material
Author(s): Jeffrey G. Hoffman
Date: 2002
Doc ID/URL: M.S. Thesis, Iowa State University, 2002. OCLC 51035549.
Description: 132 pp.
Contents: Dowel bars are used to transfer loads between adjacent pavement sections within a jointed concrete pavement. Epoxy coated steel is the most common material used for dowel bars, but steel dowel bars have been found to be susceptible to corrosion. The objectives of this research is to investigate fiber reinforced plastic (FRP) and stainless steel as alternative dowel bar materials, and to study the effects of FRP and stainless steel dowels size and spacing on load transfer behavior of concrete pavements. The load transfer behavior of the pavement was evaluated biannually by utilizing a falling weight deflectometer (FWD), measuring joint faulting and joint opening, and conducting a visual distress survey. The analyses indicate the epoxy coated steel outperformed the alternative materials. The average research lifetime load transfer for the epoxy coated steel is 91 percent, while the best performance of the alternative material at the same 12 inch on center spacing is approximately 87 percent for the stainless steel. The data also indicate the decrease in spacing, from 12 to 8 inches, increases the load transfer for stainless steel and 1.5 inch diameter FRP dowels. Although the FRP dowels with decreased spacing were outperformed by the epoxy coated steel dowels, they performed adequately. It is recommended that the current dowel bar standard continue to be implemented for concrete pavements requiring dowels as load transfer devices. However, if the pavement is to be constructed in a corrosive environment or a longer design life is desired, stainless steel spaced at 12 inches and 1.5 inch diameter FRP dowels spaced at 8 inches should be considered.

Title: Performance of Dowel Bars and Rigid Pavement
Author(s): Shad M. Sargand
Date: June 2001
Doc ID/URL: FHWA/HWY-01/2001.
Description: 40 pp.
Contents: The economic burden associated with repairing and maintaining existing highway pavements is rapidly consuming an increasingly significant portion of the annual transportation budget. One of the major areas of concern is the repair of rigid pavements resulting from premature distress at transverse contraction joints. The performance of Portland cement concrete joints in transferring traffic loads to adjacent slabs is influenced by several factors, including temperature and moisture distributions within the slabs, physical properties of the base and subgrade underlying the pavement, moisture content of the subgrade, and the type, size and spacing of dowel bars. Finite element methods have been used with some success in analyzing concrete pavement systems containing joints and cracks. The accuracy of these methods, however, depends upon how realistically the properties of the concrete and subgrade, the dowel concrete interaction, and traffic loading can be modeled. These procedures must then be verified and calibrated with data obtained on in-service pavements. To date, stresses induced in dowel bars and concrete slabs from environmental cycling and dynamic loading have not been determined in the field.

Title: Construction and performance of alternative concrete pavement designs in Wisconsin
Author(s): James Crovetti, Debra Bischoff
Date: 2001
Doc ID/URL: *Transportation Research Record 1778*, 2001: 43-53.
Description: 11 pp.
Contents: The design and performance of concrete pavement test sections constructed in Wisconsin in the summer of 1997 to validate the constructability and potential cost-effectiveness of alternative concrete pavement designs incorporating variable dowel strategies and slab thicknesses are described. To reduce the number of dowel bars across the transverse joints and remain consistent with dowel bar installation equipment currently used within the state, four alternative dowel patterns were examined. Test sections were constructed with alternative dowel materials including fiber-reinforced polymer (FRP) composite dowels, solid stainless steel dowels, and hollow core mortar-filled stainless steel dowels as well as a variable slab thickness. Postconstruction monitoring including deflection testing, joint distress surveys, and ride quality surveys have been done. Observed joint distress including minor spalling, chipping, and fraying is mainly due to joint saw cut operations. No transverse joint faulting or slab cracking has been observed. Deflection testing to date indicated general uniformity of foundation support in all test sections. Deflection testing has also been done across transverse joints to quantify deflection load transfer efficiency. Joint tests in the fall of 1997 and 1998 indicated reduced load transfer efficiencies in all test sections compared with control sections, most notably in the FRP composite dowel test sections and the placement alternative with three dowels in each wheelpath. Ride quality surveys indicated general uniformity among sections.

Title: Using fiber-reinforced polymer load transfer devices in jointed concrete pavements
Author(s): A. Shalaby, S. Murison
Date: 2001
Doc ID/URL: *Seventh International Conference on Concrete Pavements: The Use of Concrete in Developing Long-Lasting Pavement Solutions for the 21st Century*, 2001: 607-621.
Description: 15 pp.
Contents: The objective of this paper is to investigate the use of alternative dowel materials and construction to produce longer lasting joints in rigid pavements. Jointed concrete pavements require dowels to transfer the loads across transverse joints and to prevent faulting. The most commonly used dowels are made of epoxy-coated steel with a diameter ranging form 25 to 38 mm. Problems associated with dowels include corrosion of the dowel material and possible crushing of concrete surrounding of the dowel, which causes looseness of the joint and faulting. This research evaluates corrosion-free alternatives to steel reinforcing elements. The use of Glass Fiber-Reinforced Polymers (GFRP) as load transfer devices are investigated and some material characteristics and design guidelines for GFRP dowels are introduced.

Research in Progress

Title: Evaluation of Elliptical Steel Dowel Performance
Principal Investigator(s): James K. Cable, Iowa State University, (515) 294-3230, jkcable@iastate.edu.
Start Date: 5/19/2003
RIP URL: http://www.ctre.iastate.edu/research/detail.cfm?projectID=-116430456 and http://rip.trb.org/browse/dproject.asp?n=10691
Sponsor Organization: Federal Highway Administration
Contents: The objective of this research project is to determine the relative performance over time of medium- and large-sized elliptical steel dowels compared to conventional round dowels, including the impact of spacing, placement in cut or fill sections of the roadway, and constructability issues. Expected to finish 5/18/2008.