



## **Doweled and Non-Doweled Pavement Performance Over Open-Graded Base Course**

*Prepared for*  
**WHRP Rigid Pavements  
Technical Oversight Committee**

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*Transportation Literature Searches are prepared for WisDOT staff and investigators to identify completed research and other authoritative information in an area of interest. The citations below are representative, rather than exhaustive, of available English-language studies on the topic. Primary online resources for the literature searches are OCLC's [WorldCat](#) and [TLCat](#), U.S. DOT's [TRIS Online](#), the National Transportation Library ([NTL](#)), TRB's Research in Progress ([RiP](#)) database, and other academic, engineering and scientific databases as appropriate.*

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**Topic/Problem Statement:** Document literature from 2000 to the present relevant to a performance study of test sections of concrete pavement in Wisconsin. Sections feature open-graded base course that should drain well and portland cement concrete with both doweled and un-doweled transverse joints.

**Keywords:** Open-graded base course, OGBC, dowel, non-dowel, un-dowel, concrete, pavement, drainage.

### **Summary**

We found six publications addressing relationships between doweling concrete pavement and using open-graded or permeable base courses, one each in the following years: 2007, 2006, 2005, 2003, 2001 and 2000. The 2000 and 2001 papers were published by TRB, the 2003 report by Kansas DOT, and the 2006 and 2007 reports by Wisconsin DOT. The 2005 publication was a conference proceeding. We did not find any current research on this topic.

### **Citations**

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

**Title:** Analysis of Concrete Pavement Joints to Predict the Onset of Distress

**Author(s):** Robert O. Rasmussen, Andrew Agosto, Steven Cramer

**Date:** September 2007

**Source/URL:** WHRP 0092-05-05, Final Report.

[http://www.whrp.org/Research/Rigid/rigid\\_0092-05-05/0092-05-05-FinalReport.pdf](http://www.whrp.org/Research/Rigid/rigid_0092-05-05/0092-05-05-FinalReport.pdf)

**Description:** 62 pp.

**Contents:** This report documents the investigation of a 15-mile segment of doweled plain jointed concrete pavement located on Interstate 90/94 in Juneau and Sauk Counties in the State of Wisconsin. This section has experienced a particular mode of early deterioration that had not previously been reported on other concrete pavements in the State of Wisconsin. Coupled with the fact that these pavements were less than ten years old, an investigation was conducted to seek out the causes of the observed distress. Three primary objectives guided the work in this effort.

The first was to investigate the nature of the distress using advanced analytical methods including finite-element methods (FEM), validating the predictions using field observations when possible. The second objective was to identify maintenance and/or restoration activities that can be used to slow or prevent the propagation of the observed pavement distresses. Finally, current WisDOT design standards and specifications were reviewed to determine if previous changes made are likely to address the causes of the premature failure.

**Title: Cost-Effective Concrete Pavement Cross Sections – Final Report**

**Author(s):** James A. Croveti

**Date:** June 2006

**Source/URL:** WI/SPR-03-05, 2006, Final Report.

<http://www.dot.wisconsin.gov/library/research/docs/finalreports/tau-finalreports/concretecrosssections03-05.pdf>

**Description:** 99 pp.

**Contents:** This report presents the findings of a study of alternate pavement designs targeted at reducing the initial construction costs of concrete pavements without compromising pavement performance. Test sections were constructed with alternate dowel materials, reduced dowel placements, variable thickness concrete slabs and alternate surface and subsurface drainage details. Performance data were collected out to 5 and 7 years after construction. The study results indicate that fiber reinforced polymer (FRP) composite dowels may not be a practical alternative to conventional epoxy coated steel dowels due to their reduced rigidity, which results in lower deflection load transfer capacities at transverse joints. Ride quality measures also indicate higher International Roughness Index (IRI) values on sections constructed with FRP composite dowels. Study results for sections constructed with reduced placements of solid stainless steel dowels also indicate reduced load transfer capacity and increased IRI values as compared to similarly designed sections incorporating epoxy coated dowels. Reduced doweling in the driving lane wheel paths also is shown to be detrimental to performance for most constructed test sections. The performance of sections with reduced doweling in the passing lane wheel paths indicates that this alternate may be justifiable to maintain performance trends similar to those exhibited by the driving lane with standard dowel placements. Performance data from sections constructed with variable slab geometry and drainage designs indicate that one-way surface and base drainage designs are performing as well as or better than standard crowned pavements with two-way base drainage. The drainage capacity of the base layer, constructed with open graded number 1 stone, appears sufficient to handle all infiltrated water.

**Title: Prediction of top-down transverse cracking in jointed plain concrete pavement**

**Author(s):** Yanfei Peng, Will Hansen, David L. Smiley, Elin A. Jensen

**Date:** 2005

**Source/URL:** *Eighth International Conference on Concrete Pavements*, 2005: 1342-1358.

**Description:** 17 pp.

**Contents:** This paper describes the findings of a recently completed investigation by the University of Michigan to identify the causes for premature, mid-slab cracking of jointed plain concrete pavement (JPCP) in Michigan. The study found several factors are working interactively to induce slab cracking. The major factor is the support characteristics of the unbound open-graded aggregate base. Deflection testing showed a permanent loss of slab contact with the base (void) exists near the doweled joint. Time history analysis of the deflection data showed that the dowels are very likely loose. Loss of slab-base contact without pumping suggests that post-compaction under heavy vehicle loading or particle degradation is occurring. In addition, the study found that the load transfer efficiency (LTE) across joints has declined since construction. Finite element analysis (ABAQUS) was used to evaluate the extent and significance of these factors on tensile stress and fatigue cracking. Fatigue failure culminates from excessive tensile stress at mid-slab at the slab's topside outer edge. The slab stress predictions correlate well with the deflection-based fatigue model by Wu et al. (1993) suggesting that a threshold corner deflection criteria may be used to determine when loss of slab support is critical.

**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 G. Melham, Roger Swart, Sandy Walker

**Date:** November 2003

**Source/URL:** Report No. FHWA-KS-02-7, Final Report.

[http://ntl.bts.gov/lib/24000/24600/24603/KS027\\_Report.pdf](http://ntl.bts.gov/lib/24000/24600/24603/KS027_Report.pdf)

**Description:** 100 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: Characterization and modeling of axial slab-support restraint**

**Author(s):** Robert Otto Rasmussen, Dan K. Rozycki

**Date:** 2001

**Source/URL:** *Transportation Research Record No. 1778*, 2001: 26-32.

**Description:** 7 pp.

**Contents:** Slab-support interaction has long been established as an important consideration in the design and construction of concrete pavements for streets, highways, and airfields. With the current interest in design features such as open-graded permeable bases, unbonded concrete overlays, and whitetopping pavements, the need for an accurate and standard means for characterizing this behavior is evident. With respect to conventional concrete pavements, previous studies have concluded that excessive restraint between the slab and the support layers of a pavement structure can lead to pavement distresses that are ultimately detrimental to the performance of the pavement. These studies have indicated that undesirable restraint characteristics typically are caused by improper subbase design or construction. The consequences of underestimating or neglecting the support restraint characteristics have been shown to result in uncontrolled slab cracking, excessive joint movements, and underdesigned reinforcement. However, in some cases a high degree of slab-support restraint is desired, such as for whitetopping pavements, especially ultrathin whitetopping. Recent developments in characterizing and modeling axial slab-support restraint characteristics of concrete pavements are presented. Test procedures that have been developed to accurately assess the level of axial slab-support restraint present are identified, as are future enhancements to characterization and modeling of this phenomenon.

**Title: Effectiveness of analysis of subsurface drainage features based on design adequacy**

**Author(s):** Timothy Robert Wyatt, Emir Jose Macari

**Date:** 2000

**Source/URL:** *Transportation Research Record No. 1709*, 2000: 69-77.

**Description:** 9 pp.

**Contents:** To prevent the deleterious effects of undrained moisture in pavement structures, it has become common to incorporate subsurface drainage features such as permeable bases and edgedrains into pavement design. A theoretical design methodology has been developed to ensure that the level of subsurface drainage is adequate for the specific pavement structure. However, recent research has called into question the effectiveness of subsurface drainage for certain types of pavement structures. Correlating the presence of moisture-related pavement distress with drainage features has revealed that drainage features do not significantly reduce faulting of doweled jointed concrete pavements, and that edgedrains may negatively impact hot-mix asphalt pavements. However, the study in which this correlation was accomplished did not attempt to assess the adequacy of the provided drainage features using the theoretical design methodology. This research presents an alternative method of effectiveness assessment based on design adequacy. The theoretical drainage capacity of a design feature, such as a pavement base or edgedrain system, is computed using the design methodology and compared with the expected inflow to that feature. The adequacy of the design is expressed as the proportion of the computed capacity to the expected service requirement. The method is applied to cases in the Long-Term Pavement Performance database. Examples are provided in which adherence to the design methodology would have indicated that the drainage features were inadequate; however, the more simplistic observational approach would reflect poorly on the effectiveness of the provided drainage features.