ODOT Executive Summary

The Ohio Department of Transportation
Office of Innovation, Partnerships & Energy
Innovation, Research & Implementation Section
1980 West Broad Street
Columbus, OH 43223
614-644-8135
Research@dot.state.oh.us
www.dot.state.oh.us/Research

Executive Summary Report

Evaluation of Alternative Dowel Bar Materials and Coatings

FHWA Report Number:	FHWA/OH-2011/19
Report Publication Date:	October 17, 2011
ODOT State Job Number:	134411 – TPF-5(188)
Project Duration:	36 months
Start Date:	October 17, 2008
Completion Date:	October 17, 2011
Total Project Funding:	$54,000
Research Agency:	Applied Pavement Technology, Inc.
Researchers:	Roger M. Larson and Kurt D. smith
ODOT Project Manager:	Roger Green
Subject Matter Experts:	TPF-5(188) Technical Panel Members: Roger Green (Ohio); Mark Gawedzinski (Illinois); Andy Gisi (Kansas); Barry Paye (Wisconsin); Max Porter (Iowa State University); Paul Virmani (FHWA); Sam Tyson (FHWA)

For copies of this final report go to http://www.dot.state.oh.us/research.

Project Background

The inclusion of steel dowel bars to transfer forces across sawed or formed transverse joints from one concrete pavement slab to another while permitting expansion and contraction movements of the concrete has been a basic design practice in most U.S. state departments of transportation (DOTs) for many decades. However, corrosion of the steel dowels remains a common problem, especially in states that use salt and other caustic deicing chemicals for snow and ice control. Significant corrosion reduces the effective diameter of the dowel bar in the joint, often to the point where the dowel bar will fail in shear when loaded, resulting in faulting of the pavement slab. Furthermore, the corrosion can also “lock” the dowel bar into the concrete, preventing movement of the concrete during expansion and contraction and thereby leading to the development of cracking in the adjoining slabs. In the mid-1970s, state DOTs began to require that steel dowel bars be coated with epoxy or other materials to prevent corrosion, and epoxy-coated dowels became the standard for most states. Recently, a number of different alternative dowel bar materials have emerged, seeking to combine effective load transfer capabilities with enhanced corrosion resistance. While the corrosion resistance of some alternative materials have been well documented in laboratory examinations, other performance characteristics affecting service life remain to be fully evaluated, particularly in representative field installations and over meaningful time periods.

A program to evaluate two specific alternative dowel bar materials—Type 304 stainless steel and fiber reinforced polymer (FRP)—was initiated in 1998 by the Highway Innovative Technology Evaluation Center (HITEC), which was established by the American Society of Civil Engineers (ASCE) to evaluate and implement new products and materials for use in the highway market. Initial field installations of 1.5-in (38-mm) diameter FRP and stainless steel dowel bars began in 1996 in conjunction with the Federal Highway Administration's (FHWA's) High Performance Concrete Pavement (HPCP) program. Projects were completed in four States (Iowa, Illinois, Ohio, and Wisconsin) over a period of 4 years. The projects were being evaluated under a 1998 evaluation plan developed by HITEC. A draft interim report detailing the construction and early performance of the test sections was submitted in March 2005, but the HITEC program was soon terminated prior to completion of the evaluation. This research was initiated to complete the original work initiated by HITEC, with an emphasis on field testing and performance rather than on the extensive laboratory testing originally proposed by HITEC.

This research was a collaborative effort conducted with technical and financial assistance from the Illinois Kansas, Ohio, and Wisconsin DOTs, as well as the FHWA under the pooled-fund program. Additional technical expertise was provided to the research team by staff from Iowa State University and Marquette University.

Study Objectives

The focus of this project was to evaluate the long-term performance of 1.5-in (38-mm) diameter FRP bars; 1.5-in (38-mm) diameter, Type 304 stainless steel solid or clad bars; 1.5-in (38-mm) diameter, Type 304 stainless steel, concrete-filled tubes or pipe; and 1.5-in (38-mm) diameter, epoxy-coated mild steel smooth round dowels (as the control) based on over 10 years of service. In addition, it was also desired to assess the long-term (15 to 30+ years) performance and condition of conventional epoxy-coated dowel bars to determine the potential need or necessity for alternative dowel bars materials. Thus, the two major objectives of this pooled-fund project may be summarized as:

1. Evaluate the expected long term performance of 1.5-in (38-mm) diameter FRP bars and 1.5-in (38-mm) Type 304 stainless steel solid or clad bars or concrete filled tubes and cost effectiveness of these materials as alternative dowel bar materials. The focus of this evaluation is limited to seven projects sites in four states.
2. Based on the evaluation of epoxy-coated mild steel smooth round dowels used as control and on FWD testing and coring of other existing projects after 15 to 30+ years of service, determine the expected service life on which to base the cost-effectiveness of the use of higher priced alternative materials.

Description of Work

Under this project, the participating highway agencies assumed responsibility for conducting FWD testing, coring, and roughness testing on the original HITEC projects after 10 or more years of service. Moreover, participating SHAs were asked to select additional "older" projects (15 to 30^{+} years old) with epoxy-coated dowels to evaluate their expected service life. The collected information could then be analyzed to help evaluate long-term performance and identify overall trends. However, due to funding constraints, only the Ohio and Wisconsin DOTs were able to perform the field testing outlined in this revised evaluation plan, which limits the results and recommendations that can be made.

Research Findings & Conclusions

The performance of the OH 2 (eastbound) polyester resin 1.5-in (38-mm) diameter FRP dowels (3 different materials) was very poor in terms of low load transfer efficiencies exhibited in less than 10 years. This contrasted with the very good performance of 1.25-in (32-mm) diameter vinyl ester dowels on BEL-7 after 28 years (which was added to this evaluation). There was minimal deterioration of the Type 304 mortar filled stainless steel tubes.

Some FWD testing (prior to coring) and removal of 6-in (152-mm) diameter cores was conducted on the OH 2 projects, BEL-7, and projects with epoxy-coated dowels in service for 15 to 30+ years. The condition of the joints prior to coring were photographed, some FWD testing was conducted, and cores were obtained for visual inspection, for removal of the dowel bar for a visual evaluation of corrosion, and for chloride testing of the concrete at the crack face near the dowels and at the edge of the core also at dowel bar level. In addition, in an unexpected development, twelve cores on two projects were taken of 1.25-in (32-mm) plastic-coated dowels that had been under traffic 33 years, and these were observed to be in very good condition.

It was concluded that vinyl ester resin should be used for FRP dowels. No definite conclusions could be made for the expected long term performance of Type 304 stainless steel mortar filled versus the more expensive, and durable, Type 316 stainless steel clad dowels. The epoxy coating appears to have a 25 to 30 year effective service life for Ohio's environmental and traffic conditions. The excellent performance of the 1.25-in (32-mm) diameter plastic-coated dowels after 33 years of service suggests they should be considered as a feasible alternative to epoxy-coated dowel bars, along with the alternative vinyl ester FRP dowels.

Similar testing was conducted on WI-2 in Wisconsin and on older epoxy coated dowel projects. Based on the information available, it appears that the FRP composite dowels from Glasforms, and RJD Industries are polyester resin with an estimated cost of $6.11 compared to $4.00 for epoxy-coated dowels. The FRP dowels from Creative Pultrusions are reported to be vinyl ester bisphenol, an epoxy matrix. The minimum fiber content of E-glass is unknown. Initial LTE values on the FRP sections after construction varied from a high of 73 percent to a low of 62 percent. The apparent poor quality of concrete (poor condition of the core and/or significant deterioration of the joint crack face) in the cores taken for the long term (over 10 year) evaluation also likely affects the performance. In addition, in 4 of the 44 cores, either no dowel was present (1 case) or the end of the dowel was inside the core (3 cases) indicating poor placement of the dowels (inserter or dowel baskets). It is too soon to evaluate the expected long-term performance of the Type 304 hollow-filled stainless steel dowels versus the Type 316 stainless steel solid or clad dowels.

There was no apparent correlation of chloride levels with observed deterioration of the epoxy-coated dowels in either Wisconsin or Ohio. In Wisconsin, there was moderate or extensive dowel deterioration noted in many of the projects with over 20 years of traffic.

Implementation Recommendations

Based on the limited data available, the following recommendations are made:

- The corrosion potential for dowel bars varies widely throughout the U.S. State highway agencies are encouraged to conduct an evaluation of the long-term performance of epoxy-coated dowels in their states to determine if their corrosion protection performance (and, by implication, their construction specifications and quality assurance procedures) is cost-effective. There was no correlation of concrete chloride content and dowel bar deterioration observed. Visual examination of the condition of the dowel bar coating on dowels removed from 6-in (152-mm) diameter cores appears to provide adequate performance information. As a minimum, improved quality control checks to control holidays and to coat bar ends with epoxy and to ensure care is taken during shipping, storage, and installation should be implemented to help ensure long-term performance.
- Based on the results of the coring of older epoxy-coated dowel projects, it appears that the epoxy coating is effective for about 20 to 25 years in Wisconsin and 25 to 30 years in Ohio. There was substantial variation in the condition of the epoxy coating on individual projects.
- Based on field and other laboratory testing results, it is recommended that FRP dowels be manufactured with vinyl ester resin and a minimum of 75 to 80 percent E-CR glass. To promote uniformity of materials and facilitate evaluation, it is recommended that the AASHTO Materials Group develop a generic specification for FRP dowels. It is often very difficult to determine the material type in the FRP dowels currently used.
- Due to the short evaluation period (less than 13 years) it is not possible to project the long-term performance of Type 304 stainless steel versus Type 316 stainless steel so the cost-effectiveness can be determined. Continued evaluation of the field performance of Type 304 stainless steel dowels is needed. Results of accelerated laboratory corrosion tests should be relied upon for guidance until additional field performance data are available.
- Given their similar costs and excellent performance on two projects in Ohio after 33 years of service, plastic-coated dowels (AASHTO M254) should be considered as an alternative to epoxy-coated dowel bars. It is suggested that standard distress surveys of these projects be compared with similar age projects with epoxy coated dowels to support this recommendation. The Louisiana DOT has used plastic-coated dowels on their projects since the 1970s.
- Continued evaluation of the field performance of FRP dowels (and particularly vinyl ester) and the Type 304 stainless steel dowels should be continued. Also, monitoring programs should be established for any new FRP and plastic-coated dowel projects to verify their field performance and resulting cost-effectiveness.