Evaluation of Alternative Dowel Bar Materials and Coatings

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INTRODUCTION

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.

EVALUATION OF ALTERNATE DOWEL BARS

The 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.

Three types of dowel bars were used in the dowel bar project: epoxy-coated steel dowel bars, fiberglass dowel bars (manufactured by RJD Industries, Inc.), and stainless steel tubes filled with concrete. Most of the U.S. 50 project contains conventional epoxy-coated steel dowel bars. However, three specific test sections, each incorporating one of the load transfer devices under study, were set up near the western-most limits of the project in the eastbound direction to instrument dowel response and to compare the performance of the different load transfer devices.

A photo of the dowel coating from a typical core (see Figure 1) and a photo of the excellent condition of the surface of the pavement (see Figure 2) demonstrate the outstanding performance of the plastic-coated dowels.

Figure 1. Photo of plastic-coating of dowel on State Route 59 after 33 years of service

Figure 2. Photo of surface condition of pavement with plastic-coated dowels (State Route 59)

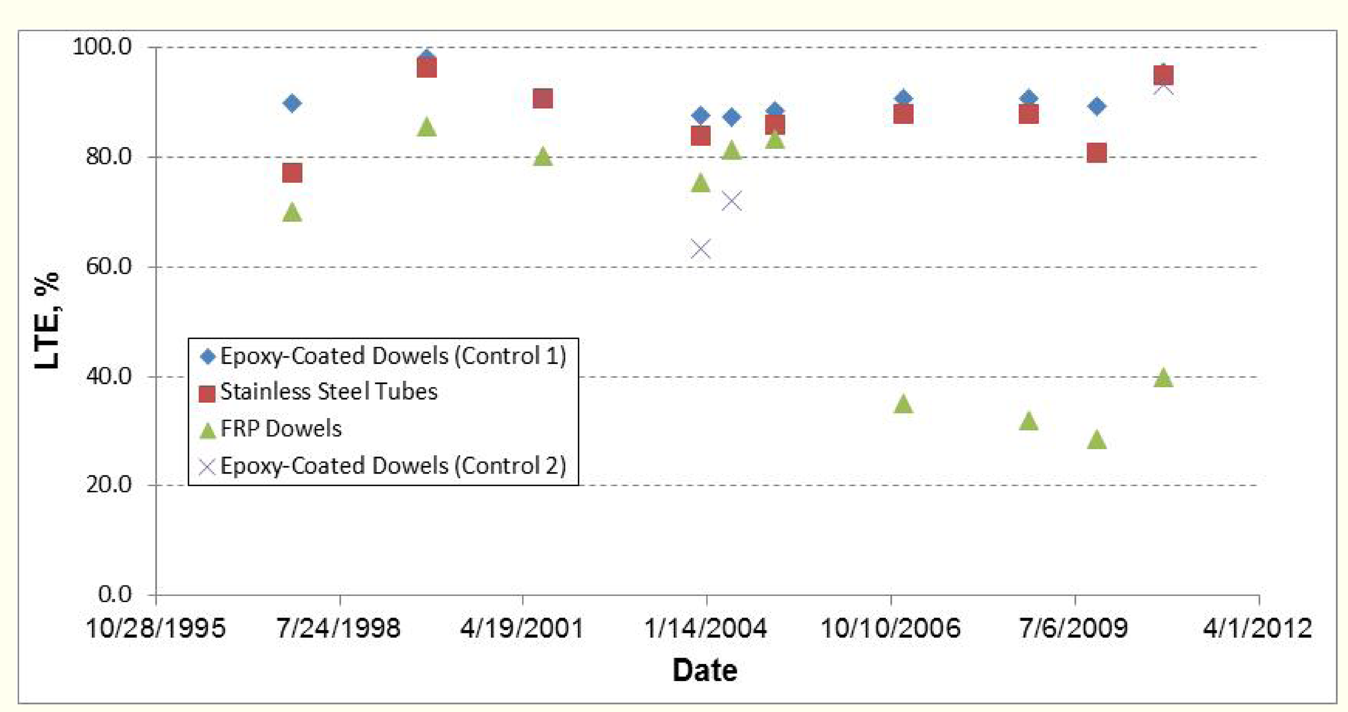

Figure 3. Summary of historical load transfer efficiency data for OH 2 EB (leave joint)

A graphical representation of the evaluation of the different types of dowel bars included in the project is provided in Figure 3 for the OH 2 EB leave joint. This figure clearly shows that the polyester resin FRP dowels evaluated in the OH 2 project exhibit far lower LTE values than their counterparts.

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 FRP 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.

CONCLUSIONS AND RECOMMENDATIONS

- It was concluded that vinyl ester resin and a minimum of 75 to 80 percent E-CR glass 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.
- 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.
- 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.
- 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.
- 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 is cost-effective.

REFERENCES

A complete reference list can be found in the full research paper: Larson R, Smith K. Evaluation of Alternative Dowel Bar Materials and Coatings, FHWA/OH-2011/19. 2011.