Design and Construction of Concrete Overlay

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INTRODUCTION

Iowa is currently one of the few states with two thin PCC overlay projects in place that are in excess of one mile in length. The first of these pavement overlays was placed in 1994 and has been used to investigate the optimum overlay for asphaltic concrete base pavements. The second pavement overlay was placed in 2002 and focused on additional investigation of the overlay depth and the impact of fibers and pavement widening on the pavement performance. These projects have proved that thin overlays are capable of becoming an alternative to asphaltic concrete overlays.

As a result of the previous work in Iowa, a need for a design manual for the engineer to use in the selection of pavement rehabilitation candidates for PCC widening and overlay projects was identified. This course covers the research results of the existing PCC overlay research in Iowa and nationally into an implementation mode.

This course seeks to answer some of the current issues in PCC overlay construction:

1. Selection criteria for implementation of successful PCC overlays, such as traffic needs, climate, underlying pavement condition, and depth of each pavement layer.
2. Traffic control requirements for various traffic volumes and mixes of vehicles.
3. Consideration of single lane paving techniques.
4. Design relationships:
    a. Traffic volume and mix vs. overlay depth
    b. Widening depth and width vs. structural enhancement of overlay
    c. Structural evaluation of underlying pavement vs. overlay depth
    d. Fiber contribution vs. overlay performance.
    e. Need for widening tie bars, size, spacing, and method of placement.
5. Design and performance of the stress reliever layer materials, surface texture, and bonding capability.
6. Structural evaluation of the impact of the widening unit and the joint spacing of the overlay on the long-term performance of the pavement.

Objectives

The objectives of this course focuses on four areas:

1. Conduct of a structural analysis of the overlay and widening unit contributions to stress reductions and extended pavement life of the composite pavement.
2. Development of construction guidelines for construction of thin concrete overlays and widening units and a catalog of designs employed.
3. Development of an overlay design procedures for thin PCC overlays and widening units.
4. Validation of the structural analysis and design procedure with field load tests and strain measures for the various pavement layers of the existing two material/layer pavements.

Plan

This course uses the two Iowa PCC overlay projects as a basis for analysis of the performance of various design components. Those pavements included the Iowa Highway 21 (7.2 mile) section from U.S. Highway 6 north to Iowa Highway 212 and the Iowa Highway 13 project from Manchester north to the junction of Iowa Highway 3.

A finite element computer analysis coupled with field strain gage installation was used for the structural analysis. The details of the field installation and the results are shown in Part I of this report.

Individual parts of the project were subdivided into the following tasks:

Task 1. Structural Analysis

1. Field evaluation and validation of strain measures in two existing overlay research pavements in Iowa to validate the current finite element results for the unbonded overlays.
2. Enhancement of previous structural analysis of the various overlay joint patterns and widening unit combinations of depth vs. width impact on the stress/strain imparted to the underlying pavement layers and life of the overlay.
3. Evaluation of the impact of the reinforcement ties between the widening unit and the overlay to include the following:
    a. Slab sizes, including, but not limited to 2x2, 4x4, 4.5x4, 5x5, 5.5x5.5, 6x6, 9x9, 10x10, 11x11, 12x12, and 12x15 feet.
    b. Overlay depths of 2, 3.5, 4, 4.5, and 6 inches.
    c. Widening unit, varying in width from 1 ft. to 5 ft. in one-foot increments in conjunction with a constant depth of 8 inches.

Task 2. Development of guidelines for the selection of candidate projects for PCC overlays

1. Structural and visual evaluation of the existing pavement layers.
2. Estimation of the future traffic needs.
3. Evaluation of traffic control needs during construction.

Task 3. Development of draft design guidelines for the overlay and widening units

1. Design of depth and width to meet traffic needs and control.
2. Use of fibers and widening tie methods.
3. Design of widening units, overlay joint spacing, and widening connection to existing pavements.

Task 4. Innovation

1. Consideration of new paving techniques to enhance pavement overlay construction and/or reduce traffic control problems during construction.

2. Consideration of new ways to introduce fibers into the mix.
3. Consideration of new joint forming methods to reduce construction time.
4. Consideration of design applications to bus loading areas and intersections or parking lots.

Task 5. Demonstration and validation

1. Development of a demonstration project or projects to illustrate the results of the research.
2. Validation of the results of the structural design enhancements with a field demonstration project.
3. Development of the project report and implementation presentations.
4. Evaluation of the resulting field demonstration project after one year.

The course divided into two major areas of structural analysis and design process development. These are reported on in the same order in the following portions of the report.

PART I—ANALYTICAL STUDIES AND FIELD TESTING

Background

Resurfacing hot mix asphalt (HMA) pavements with thin Portland Cement Concrete (PCC) overlays, or “whitetopping” as it has come to be known, is a concept that dates back to 1918. This approach has seen a large increase in use in the past 15 years due to improved whitetopping technology and the success of several high-profile projects (NCHRP 2002). Whitetopping provides several advantages to the conventional resurfacing of pavements with HMA. It significantly reduces time and delays associated with pavement maintenance utilizing asphalt. PCC surfaces also have proven durability and long-term performance, which allows for longer life at lower life-cycle costs as compared to asphalt surfaces (Burnham and Rettner 2003).

The state of Iowa is one of several states known for the large amount of PCC pavements. The original design life of the initial pavement systems was established as 20 years, and most of the systems had reached or exceeded the design life by the 1970s. These pavements were then continually resurfaced and possibly widened with asphalt cement concrete (ACC) to extend the life for another 10 to 15 years or until funding could be obtained to replace the pavements (Cable et al. 2003; Burnham and Rettner 2003). Due to the shorter design life and higher maintenance costs of asphalt pavements throughout that design life, whitetopping presents an attractive, lower cost alternative to continued pavement rehabilitation of asphalt surfaces.

In 1994, the Iowa Department of Transportation (Iowa DOT) initiated an ultra-thin whitetopping (UTW) project on a 7.2-mile segment of Iowa Highway 21 in Iowa County, near Belle Plaine, Iowa. The objective of that research was to investigate the interface bonding condition between an ultra-thin PCC overlay and an ACC base over time, with consideration given to the combination of different factors, such as ACC surface preparation, PCC thickness, the usage of synthetic fiber reinforcement, joint spacing, and joint sealing. That research continues to be one of the most referenced in demonstrating the applicability of whitetopping as a viable rehabilitation option.

In 2002, a follow-up project was initiated by Iowa DOT to investigate and verify the findings from the 1994 study (Cable et al. 2003). For this purpose, a 9.6-mile long stretch of Iowa Highway 13 (IA 13) that extends from Manchester, Iowa, to Iowa Highway 3 in Delaware County was selected as the test site. The pavement section consisted of a bottom PCC layer constructed in 1931 that was 18 ft wide, with a thickened edge that is 10″ at the edges and 7″ at the centerline of the roadway. The concrete pavement was used as the driving surface until subsequently overlaid with 2″ of asphalt concrete in 1964 and with another asphalt concrete overlay of 3″ in 1984.

Whitetopping was utilized in the summer of 2002 to rehabilitate the Iowa Highway 13 roadway and was applied considering the following variables: ACC surface preparation (milled, one-inch HMA stress relief course, and broomed only); use of fiber reinforcement in concrete (polypropylene, monofilament, proprietary structural, and no