



Project Summary

Texas Department of Transportation

5-4035-01: Construction and Evaluation of Post-Tensioned Prestressed Concrete Pavement

Background

Cast-in-place post-tensioned concrete pavement (PCP) is unique in that pre-stress is applied to the concrete slab so that cracking can be prevented and slab thickness reduced. The design philosophy and construction procedures of PCP are quite different from those of normal concrete pavement types. There are a few PCP pavements built around the world. The Texas Department of Transportation (TxDOT) built a one-mile long 6-in PCP section on IH-35 in the Waco District in 1985. The performance of the section has been excellent. Encouraged by the performance of the section, TxDOT decided to build another PCP project on IH-35 in Hillsboro. The construction of 9-in thick PCP with mostly 300-ft long slabs on IH-35 in Hillsboro started in May 2008. At this point, there are no standardized design procedures or construction specifications for PCP. The purpose of this implementation project was to develop design standards, evaluate early-age behavior of PCP pavement, and evaluate construction procedures in order to identify issues raised during the pre-construction and construction phases, with an ultimate goal of developing improved design and construction procedures.

What the Researchers Did

For the development of plans, specifications, and estimates (PS&E) for the project, researchers developed design standards and special specifications based on past experience and theoretical analysis. To evaluate the early-age behavior of a PCP slab due to environmental loading and post-tensioning, various gages, including concrete temperature and moisture sensors, vibrating wire strain gages, linear variable differential transducers (LVDTs), and in-situ coefficient of thermal expansion (CTE) and drying shrinkage of concrete sensors were installed in the 300-ft long slab. A semi-permanent data logger was installed. Data was periodically downloaded and analyzed. The information from this field testing was used to calibrate the mechanistic model developed to analyze the behavior of PCP slabs. The unique nature of PCP construction was closely evaluated in the field. Issues raised during pre-construction and construction phases were identified, discussed, and solutions were proposed and implemented.

What They Found

Summary of the findings from the evaluations of early-age behavior of PCP slab is as follows:

- The compressive stress introduced by longitudinal post-tensioning varied along the slab length, with a maximum near the armor joint and a minimum at the center of the slab.
- The distribution of longitudinal slab movement was nonlinear along with the distance from the slab center.

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Project Completed: 8-31-09

- The effect of concrete creep and shrinkage was observed.
- Temperature distribution along the slab depth was non-linear with the maximum gradient near the surface. Relative humidity (RH) in the concrete varied little except near the surface. Concrete with a low water-cement ratio and good curing appear to be responsible for the little variations in RH.

The construction of PCP was different from that of normal concrete pavement types. Also, prior to and during the construction of PCP, a few issues were identified that needed resolution. Summarized below are the findings from the field evaluations.

- Installing reinforcement (transverse and longitudinal tendons) and armor joints was time-consuming and labor intensive. Installing central stressing pockets also required a substantial amount of labor.
- The production rate of PCP was limited due to (1) time required to install reinforcements, and (2) high man-hour operations needed for post-concrete placement, such as post-tensioning.
- Due to the multi-phase construction of PCP slabs, transverse post-tensioning had to be continuous at longitudinal construction joints. Due to the use of a slip-form paver, the use of tendons was not feasible, and a 1-in diameter post-tensioning bar was used.
- When the concrete was placed at cold temperatures, strength gain was slow and 1,000 psi compressive strength was not achieved within 8 hours, which was the latest timing for initial post-tensioning application. In cold weather, post-tensioning force was reduced proportionately to the strength at 8 hours, as long as strength was greater than 600 psi.
- Bars were driven into the subbase to provide rigidity of the reinforcement in PCP. The effect of these bars on the behavior and long-term performance of PCP is not known.

There was a substantial difference (more than 6 times) in concrete displacements due to initial post-tensioning between actual measurements and predicted values from PCP 3.0. It was postulated that this difference was due to subbase friction or the use of vertical bars to provide rigidity to the reinforcements.

What This Means

PCP is an improved pavement type with numerous advantages over conventional concrete pavement types. However, there are still a number of issues regarding constructability of PCP. PCP may be the best solution in the future when the cost of materials (concrete and steel) may be too expensive to be able to construct thicker sections of continuous reinforced concrete pavements (CRCP). The labor intensive nature of reinforcement placement and stressing pocket installations and the resulting low production rate are the disadvantages that need to be resolved. The use of two layers of polyethylene sheets to reduce the subbase friction and other means for providing the rigidity of the reinforcement system that will not restrain concrete volume changes are needed.

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