Project Summary

Texas Department of Transportation

0-6190: Use of Dowel Bars at Longitudinal Construction Joints

Background

Tie bars are used at longitudinal construction joints (LCJs) in Portland cement concrete (PCC) pavement primarily to keep lanes from separating. Currently, subgrade drag theory (SGDT) is used to design tie bars at LCJs. SGDT requires more tie bars and transverse steel as more lanes are tied together. As more lanes are tied together due to ever-increasing traffic volume, concerns about the potential for longitudinal cracking and the required use of larger amounts of transverse steel have led to the use of dowel bars at LCJs. To reduce the potential for longitudinal cracking when multiple lanes are to be tied together, the Houston District of the Texas Department of Transportation (TxDOT) started using dowels at LCJs. However, a survey of a number of state highway agencies (SHAs) revealed that few SHAs have guidelines and design standards for the use of dowel bars at LCJs and no in-depth studies conducted in this area have been identified. Accordingly, it is necessary to provide mechanically sound information on whether dowel bars are really needed at LCJs. If so, when and where they should be placed, as well as what potential problems could arise, should be determined in order to minimize the ambiguity associated with the design of dowel LCJs and to have better-performing PCC pavements with a minimum longitudinal cracking potential.

What the Researchers Did

The primary objective of this research project was to develop rational guidelines for the use of dowel bars in LCJs. To thoroughly investigate concrete slab behaviors, field testing was conducted in two new continuously reinforced concrete pavement (CRCP) construction projects in Texas. Concrete strain gages, concrete displacement gages, and steel strain gages were installed in each test section. To achieve the primary objective of this study in a more effective way, theoretical analysis was performed along with field experimentation. Field performance evaluations of CRCP with multiple lanes tied together were also conducted. An improved numerical model based on plane strain theory was developed to analyze a section of concrete pavement with tie bars at LCJs. To verify the validity of the numerical model, the numerical results were compared with the field data and a strong correlation was observed. The influences of multiple lane ties and pavement geometries on the stresses in concrete and tie bars were investigated through parametric studies using the numerical model.

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What They Found

The findings from the field experimentations can be summarized as follows:

- Concrete temperatures measured at various depths from the concrete placement showed substantial variations through the slab depth. Concrete slab displacement measurements at the free edge exhibited daily curling behavior.
- The opening of LCJs at an early age resulted mainly from the drying shrinkage of concrete. In later stages, the displacements of concrete at LCJs in a transverse direction cycled in a large range stably. LCJs moved more than the longitudinal warping joints (LWJs).
- The displacements of concrete at LCJs were larger in the doweled section than in the tied section, indicating that tie bars restrain concrete elements more effectively. However, larger transverse concrete stresses near LCJs were observed in the tied section than in the doweled section.
- Tie bar stresses increased rapidly in areas closer to the LCJ. Lower tie bar stresses developed when tie bars were placed at smaller spacing.

The following conclusions, based on numerical results, were reached:

- Transverse concrete stresses at the top of the slab increase as up to 4 lanes are tied together. The increase in concrete stresses becomes minimal when more than 4 lanes are tied together. This minimal increase is due to the bond slip between concrete and tie bars.
- Concrete with a higher coefficient of thermal expansion (CoTE) produces larger concrete stresses in a transverse direction than concrete with a lower CoTE.
- The use of dowel bars in LCJs makes each tied lane behave independently. Transverse concrete stress and resulting longitudinal cracking potential decrease with the use of dowel bars at LCJs, but the lane separation potential becomes larger.
- Transverse concrete stress at the top of the slab increases as the tie bar is placed closer to the concrete surface.

What This Means

Field experiments revealed that SGDT – currently used for tie bar design – is not adequate to accurately analyze the behavior of concrete pavements. Numerical analysis showed that, although the stress in tie bars and concrete increases as up to 4 lanes are tied together, the increase becomes minimal for pavement with more than 4 lanes tied together due to bond slip. There are many miles of PCC pavements in Texas where more than 4 lanes are tied together. Field performance evaluations indicate that PCC pavement sections with more than 4 lanes tied together show no longitudinal cracking distresses due to tying multiple lanes together. Accordingly, the current use of dowels in LCJs is not recommended as it is unnecessary and will increase the potential for lane separations.

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