0-7011: Evaluation of Seamless Bridges

Background

The seamless bridge concept eliminates expansion joints between the bridge and the pavement, which can significantly reduce long-term maintenance costs and improve durability of the primary load-carrying components. Originally proposed in Australia, seamless bridges utilize continuously reinforced concrete pavement (CRCP) in which a transition zone is employed between the bridge deck and the CRCP to accommodate time-dependent deformations and stresses induced by shrinkage, creep, thermal strain, embankment settlement and traffic loads.

Limited experimental and analytical research has been conducted on the performance and design of seamless bridge-CRCP systems. The primary goal of the research study is to study the behavior of seamless (jointless) bridge-pavement systems and propose general design recommendations for practical applications in the U.S. A detailed overview of all aspects of the study are provided in the Project 0-7011 final research report.

What the Researchers Did

The research study included experimental testing and numerical modeling to obtain and develop much needed experimental data and analytical tools to study the performance of seamless systems, identify design issues, and propose design guidelines for the U.S. practice. The following major tasks were completed on this project:

1. A two-phase experimental program consisting of unit-cell direct shear tests (Phase I) and large-scale push-off tests (Phase II) was performed to characterize the interaction at different interfaces between concrete pavement and common base materials, and to identify candidate bond breakers for the transition zone in a seamless bridge system. The work was conducted at the Ferguson Structural Engineering Laboratory at The University of Texas at Austin. Eight interface materials were examined with an intent to break the bond and control the level of interface restraint, including 1-in.-thick HMA layer, woven-geotextile, non-woven geotextile, felt paper, and various types of polyethylene (PE) sheets. The effects of cyclic displacement demands on the interface shear resistance were investigated.

2. Two types of numerical models were developed using commercial finite element analysis software to analyze the system behavior. First, a structural model of the entire seamless bridge-pavement system was used to investigate the axial response of the system. Second, a more detailed continuum finite element model of the transition zone was used to analyze the response of this zone of the pavement due to combined axial and out-of-plane (vertical) effects, when subjected to differential embankment settlement, vehicular loads in addition to temperature effects. Numerical parametric studies were conducted for a range of interface properties, bridge and pavement geometries and configurations representative of those commonly found in practice to identify critical factors that affect the response of seamless systems.

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3. Based on the results and findings of the experimental testing and numerical modeling, general design recommendations were proposed, including the interface materials (bond breakers) for the transition zone, design verification criteria and design detailing. A simplified analytical method for the axial response of the seamless system, and a simplified analytical method to conduct the linear analysis of the approach slab due to combined out-of-plane and axial effects with cracked sectional properties were developed.

4. An instrumentation plan including the measurement of concrete and steel strains, longitudinal displacement, embankment settlement, was developed for future potential implementation projects when a suitable bridge is identified.

What They Found

1. Felt paper and double-sided textured linear low-density polyethylene (LLDPE) sheet are recommended as bond breakers for the transition zone, which provide a friction coefficient of 0.7 and 0.4, respectively. Both materials provide a stable steady coefficient of friction over cyclic movements due to temperature changes.

2. The axial response of the seamless system is mainly controlled by the magnitude of temperature changes. The coefficient of friction at the slab-base interface significantly affects the axial response, with a larger value leading to higher force demands and a shorter length of the transition zone. The performance of the seamless system in the case of temperature decrease, which causes tensile forces in the system, is more critical as concrete cracks. The critical regions are identified as the approach slab near the bridge abutment and link slabs, where a relatively large strain demand is expected due to the seamless connection. The out-of-plane effects increases the tensile strain demand at the top of the approach slab at the bridge end in addition to the effects of temperature decrease.

3. General design recommendations regarding the longitudinal reinforcement ratios are provided for the seamless system, as follows: 1) increase for the transition slab and approach slab compared to that in a conventional design, and a gradual increase toward the bridge provides an efficient solution; 2) increase significantly for the bridge link slabs.

What This Means

A seamless bridge-CRCP system can accommodate the deformations and stresses induced by thermal effects, embankment settlement and traffic loads without expansion joints, if a proper design of the length of the transition zone, and amounts of longitudinal reinforcing steel in the transition slab, approach slab, and link slabs is provided. The use of recommended bond breakers (i.e., felt paper or textured LLDPE sheet) avoids large tensile strain demands and severe cracking in the concrete slab and overly-long transition zone. Following the proposed simplified analytical method, the minimum required length of the transition can be determined. The axial and out-of-plane response can be determined as well. The amounts of reinforcing steel can be iteratively determined to satisfy both strength and serviceability limit states.

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