Texas Department of Transportation

CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY REPORT

0-6936: Development of Integral/Semi-integral Abutments for TxDOT Bridges

Background

Semi-integral bridges constitute a promising alternative to conventional TxDOT bridges because they eliminate the need for deck expansion joints, which may significantly reduce bridge maintenance costs and potentially result in significant savings over the bridge service life. Adopting semi-integral bridges is particularly relevant to Districts with comparatively cold winters (e.g., Amarillo), where the use of deicing salts has resulted in significant joint maintenance problems. However, the elimination of expansion joints requires careful consideration because of the soil-structure interaction between the bridge structure and abutment backfill caused by the bridge's daily and seasonal thermal expansion/contraction.

What the Researchers Did

This study includes an initial comprehensive evaluation of the state-of-the-practice in the US regarding the adoption of integral and semi-integral bridges. It also involved a large-scale experimental study focusing on the effect of cyclic movements on the potential buildup of lateral earth pressures acting on the backwalls of a semi-integral bridge. In addition, a numerical evaluation was conducted to understand the variables governing the performance of these types of bridge structures. However, the most relevant aspect of this study involved the design of a monitoring system, its installation, and its subsequent operation for two pilot semi-integral bridges in Texas. These comprehensive field monitoring projects allowed evaluation of the effect of daily and seasonal temperature changes on the displacement of various bridge components, of the changes in abutment earth pressure, of unexpected outcomes regarding foundation interaction, on the buildup of lateral earth pressures against the bridge backwalls (ratcheting), and on the evolution of backfill settlements.

What They Found

The multiple components of this study allowed reassessment of the benefits and design considerations regarding adopting semi-integral bridges in Texas. The findings confirmed and quantified the continued increase in backfill lateral earth pressures against the bridge backwalls (ratcheting). This aspect can be designed for, but that requires proper quantification. In addition, the study identified the development of backfill settlements, which resulted in a loss of vertical support for the approach slabs. Also, the results of the field monitoring program identified that, unlike common design assumptions, the expansion/contraction of the bridge deck due to temperature changes is asymmetric, resulting in the overall displacement of the bridge superstructure towards one of the ends of the bridge structure. A reasonably unexpected finding was that thermal expansion/contraction of the bridge deck results in cyclic lateral loading of the abutment caps and the bridge foundations despite a lack of rigid connection between the foundations and the superstructure. The cyclic loading of the foundations was also found to cause the accumulation of plastic strains in the foundation soil. The causes of the aspects of the performance of semi-integral bridges that differ from conventional bridges were ultimately successfully identified through monitoring of two semi- integral bridge structures, resulting in recommendations offered to minimize the occurrence of such issues in future semi-integral bridges while capitalizing on the benefits of the semi-integral bridge technology.

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What This Means

The current approach adopted by TxDOT to place backfill material in bridges, such as the recently evaluated China Creek Bridge, located near Wichita Falls, does not include any form of confinement. Instead, this project recommended design changes, particularly regarding the backfill placement requirements. Specifically, an important outcome of the project is the adoption of geotextile confinement during backfill compaction (See Figure 1). This approach would minimize both lateral earth pressures and backfill settlements. In fact, the researcher's design recommendations (including the adoption of a geotextile- confined backfill) have already been incorporated into the design of two new semi-integral bridges in the Amarillo District. Specifically, construction of Phase 1 of a project in FM 291 (at Whitefish Creek) has already started by the time of completion of this study (August 2023), while construction of Phase 2 of the same bridge and that of a second project in FM 1259 (at Tierra Blanca) are imminent and awaiting notices to proceed.

The prompt incorporation of Project 0-6936's outcomes into the design of new TxDOT bridges, even before this research project concluded, emphasizes the relevance of the research findings. While time-sensitive, such prompt incorporation of research outcomes provides an opportunity to monitor the new design approach by initiating a field monitoring program of at least one of the new semi-integral bridges in the Amarillo District. The geotextile-confined backfill would benefit from monitoring monitored to assess its impact on (1) the lateral earth pressures induced due to cycles of temperature-induced backfill movements and (2) the settlements of the backfill material. The new approach is expected to reduce lateral earth pressures and decrease settlements.

In addition, Project 0-6936 included the design, installation, and operation of a field monitoring system for the semi-integral bridge at China Creek. This monitoring system remains fully operational, represents TxDOT assets that exceed 1M dollars, and continues to collect data wirelessly from approximately a hundred sensors. Consequently, extending the collection of performance data from the bridge will allow (1) assessment of the long-term lateral earth pressures that develop against bridge abutments in semi- integral bridges and (2) quantification of cyclic lateral pressures in instrumented drilled shaft foundations, which will allow refinement and validation of current design approaches for drilled shafts not only in semi- integral but also in conventional TxDOT bridges.

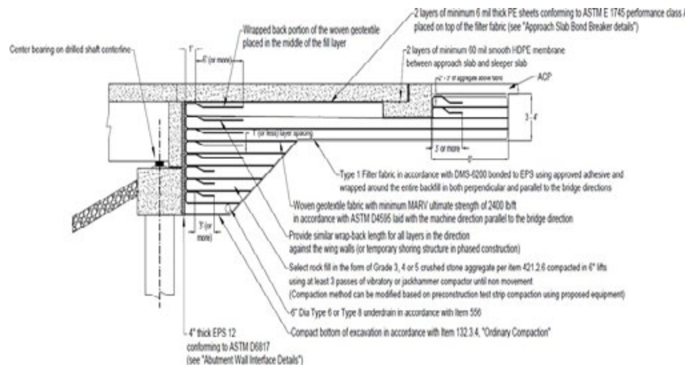

Figure 1. Detail of the semi-integral abutment in the Amarillo bridge, designed by TxDOT incorporating design recommendations from Project 0-6936. Note the presence of geotextiles confining the backfill material.

For More Information

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