VDOT Virginia Department of Transportation

Virginia Center for Transportation INNOVATION & RESEARCH

Research Brief

VCTIR 13-R7RB April 2014

Thermal Response of Integral Abutment Bridges with Mechanically Stabilized Earth Walls

Perspective The Virginia Department of Transportation (VDOT) promotes the use of integral bridges because they have lower construction and maintenance costs plus a longer service life than conventional bridges. What accounts for these savings, in large part, is that integral bridges, unlike conventional structures, are designed with no expansion joints.

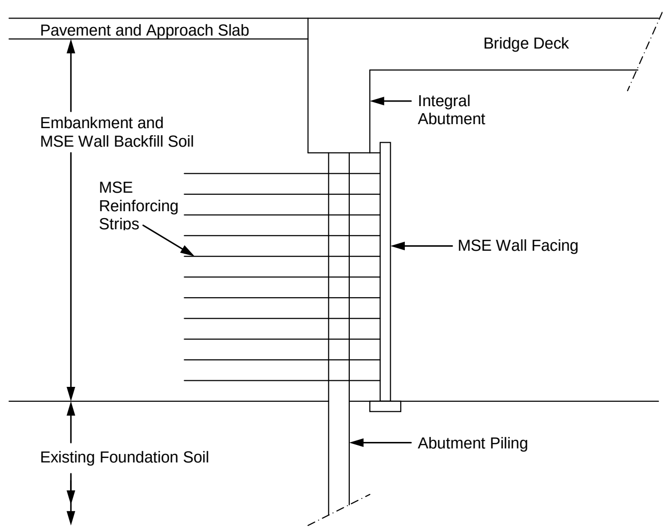
The objective of this study was to analyze fully integral abutment bridges with mechanically stabilized earth (MSE) retaining walls to determine the interactions among integral abutments, foundation piles, embankment soil and MSE walls, using geotechnical numerical modeling. The lack of expansion joints in an integral bridge contributes to the complexity of these interactions.

In particular, VDOT's Structure and Bridge Division engineers wanted to avoid damage to integral bridge / MSE wall systems that could occur as a result of fluctuations in daily and seasonal ambient air temperatures. An integral bridge's thermal response induces movement in the bridge's abutment piles, which could cause damage as they interact with the MSE wall facing. Prior to this study, practical methods to estimate the magnitude and distribution of associated loads were not available.

An important product of this study was an easy-to-use Excel spreadsheet for VDOT bridge designers, called "IAB," for "integral abutment bridge." It can calculate thermally induced incremental forces, moments, pressures and displacements on integral abutments with foundation piles in MSE wall backfill. The spreadsheet enables more reliable design of this type of abutment system. The study, sponsored by VDOT's research division, the Virginia Center for Transportation Innovation and Research (VCTIR), is consistent with VDOT's goal of greater implementation of integral bridges.

When used to retain the embankment of an integral bridge, MSE walls may serve to reduce the footprint of the abutment as compared to conventional sloping fill abutments. MSE retaining walls are constructed of un-mortared face block bolted to long metal reinforcing strips. The strips extend back into, and are layered over by, fill soil to bind the wall to the bridge embankment. This type of design saves money because the bridge span can be shorter and less land may be needed for the bridge's required right of way. Integral bridges with MSE retaining walls are particularly suited for high-density urban environments.

Background When a fully integral bridge is built with MSE wall abutments, the foundation piles are driven close to the wall face. As the bridge contracts and expands in response to ambient air temperature changes, the resulting movement is transferred directly to the abutments. This causes the foundation piles to deflect toward and away from the face of the MSE wall. The deflecting piles exert forces on the wall facing panels and the metal reinforcing strips.

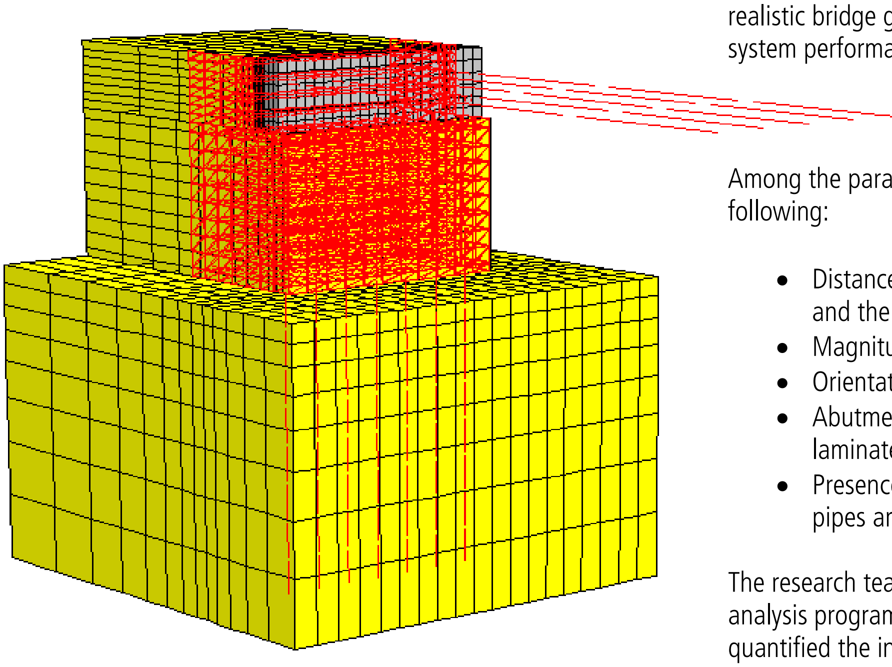


Profile view of MSE system around piling supporting integral bridge abutment

VDOT's Staunton District structure and bridge engineer proposed this modeling study to examine existing mitigation measures and to make it possible to prepare bridge designs based on a solid understanding of the loads and interactions in integral abutment bridges with MSE walls.

For the full report, search 13-R7 at vtrc.virginiadot.org. For more information about the study, contact Edward J. Hoppe, VCTIR associate principal research scientist, Edward.Hoppe@vdot.virginia.gov.

VCTIR's Geotechnical Research Advisory Committee endorsed the project as a high-priority research need. VCTIR contracted a team from Virginia Tech's Department of Civil and Environmental Engineering with expertise in geotechnical numerical modeling to perform the study.



This mesh diagram represents a numerical model, compiled in FLAC3D software, of a bridge abutment. It is composed of more than 10,000 elements. The figure displays a concrete abutment, foundation soil and mechanically stabilized earth (MSE) wall.

Research and Recommendations The research team surveyed transportation agencies in the United States and Canada to determine current integral bridge design practice. The researchers developed a finite difference model to represent the behavior of integral bridges with MSE walls. VDOT and VCTIR advised the Virginia Tech researchers regarding current design methodology and a range of practical bridge design configurations to model. The research team validated the model with data from field measurements collected from other studies.

The team conducted more than 60 three-dimensional numerical analyses to investigate and quantify how various configurations of structural and geotechnical bridge components behave during thermal expansion and contraction. They systematically varied parameters in a base-case model to determine the influence of a wide range of realistic bridge geometries and materials on the overall system performance.

Among the parameters varied in the modeling were the following:

- Distance between the back of the MSE wall facing and the abutment piles
- Magnitude of the abutment thermal displacement
- Orientation of the foundation piles
- Abutment design details, e.g., dowel connections, laminated pads or solid abutment
- Presence or absence of corrugated sand-filled steel pipes around abutment piling

The research team developed the model using a numerical analysis program called FLAC3D. The results of the modeling quantified the influence of design parameter variations on the effects of thermal displacement on system components. To make this information practical and readily accessible to VDOT integral bridge designers, the team developed the IAB spreadsheet. This product allows a designer to enter various design parameters and evaluate thermally induced loads resulting from MSE wall and integral abutment interaction.

The study found that the installation of corrugated sand-filled steel pipe sleeves around abutment piles does not reduce stresses in the piles because the loose sand inside the sleeves becomes densified after cyclic loading due to thermal displacements. The study estimated the cost savings from leaving these pipes out of future integral bridge construction.

In addition, the study recommended numerous practical modifications to VDOT's integral bridge design practice.

The Virginia Center for Transportation Innovation and Research (VCTIR) is proud to contribute to VDOT's reputation as a national transportation leader. VCTIR greatly appreciates the cooperation and support of VDOT and the Federal Highway Administration.