0-5849: Evaluating Existing Culverts for Load Capacity Allowing for Soil Structure Interaction

Background

This report presents findings of a two-year research study of culvert load rating practices and procedures as applied to reinforced concrete box culverts that have been designed, built, and maintained by the Texas Department of Transportation (TxDOT). The problem facing TxDOT is that when roads or rights-of-way are widened and/or raised, culverts which pass under them need to be reassessed for the extension and/or increased soil loads. These in-service culverts, which may have performed satisfactorily for many years, must be reanalyzed using current American Association of State Highway and Transportation Officials (AASHTO) methods. AASHTO has revised their culvert rating guidelines upward over the years to impose larger loads on buried structures, so this means that many older, serviceable culverts, reanalyzed in the process of designing extensions, are seen as deficient, requiring either retrofit or replacement.

What the Researchers Did

The research effort for the first year of this project was directed toward developing a new, improved culvert rating procedure. Requirements were that the procedure be based on authoritative AASHTO code, that it be conceptually clear and generally applicable to many analytical methods, and that it incorporate escalating levels of analytical rigor. To this end, the research team developed and published TxDOT's *Culvert Rating Guide*, which is the main deliverable for this project.

The second year of research effort was directed toward validating the practices and procedures for culvert load rating recommended in the *Culvert Rating Guide*. This involved three research thrusts. First, the *Culvert Rating Guide* was applied to a statistically representative sample of 100 of TxDOT's 1477 unique culvert designs. Rating these 100 culvert designs provided assurance the *Culvert Rating Guide* could be used for the full population of TxDOT's culverts, and not just a few select cases. Second, a parametric study was performed to evaluate six independent variables associated with culvert load rating. This helped determine the sensitivity of the culvert rating process to the different variables. Third, the research team instrumented and load-tested three in-service culverts in the field. This work facilitated a comparison of measured demand moments to predict values obtained through analytical modeling as per the *Culvert Rating Guide*.

Research Performed by:

Center for Multidisciplinary Research in Transportation (TechMRT), Texas Tech University

Research Supervisor:
William D. Lawson, TechMRT

Researchers:
Priyantha Jayawickrama, TechMRT
Charles Newhouse, TechMRT
Timothy Wood, TechMRT

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What They Found

The *Culvert Rating Guide* articulates a clear and repeatable load rating procedure designed to satisfy current AASHTO specifications and provides for four levels of increasing demand modeling sophistication. These four levels are: Level 1, culvert specific frame analysis programs as typified by CULV-5; Level 2, two-dimensional general frame analysis programs as typified by RISA-2D with spring subgrade support; Level 3, two-dimensional finite element soil-structure interaction programs as typified by RISA-2D with linear elastic finite elements; and Level 4, higher order generalized programs including non-linear two-dimensional models and three-dimensional models. The *Culvert Rating Guide* provides specific direction for production load rating using the first three methods.

Validation of the *Culvert Rating Guide* was accomplished through a breadth and depth approach. The breadth results showed that in general, the Level 2 analysis produces marginally higher load ratings than the Level 1 analysis. It also showed that the Level 3 method can produce much higher load ratings if the soil is sufficiently stiff. However, if culvert backfill is of poor quality, the higher-level load rating may be less than that determined by Level 1. Parametric studies showed that culvert load ratings are highly sensitive to the modulus of elasticity for the soil in the Level 3 analysis. The depth of fill is also a highly sensitive parameter; therefore, culverts should be load-rated at their actual depth of fill and culvert designs should be evaluated at both their maximum and minimum depths. The instrumented load test data indicated that, within the tested conditions, the culvert load ratings for each model are conservative. This means that each of the three models can be safely used for culvert load rating. However, this research only considered cast-in-place reinforced concrete box culverts under drained backfill conditions. Relative to culvert design, only the lowest order model, *i.e.* CULV-5, should be used.

What This Means

The *Culvert Rating Guide* represents a significant improvement in TxDOT's culvert load rating capabilities. It provides clear guidance for repeatable load rating, including the ability to reduce excess overconservatism in load ratings by taking into account soil-structure interaction effects. Implementation of the *Culvert Rating Guide* into TxDOT's culvert load rating practices and procedures will help to provide safe, effective and efficient movement of people and goods in Texas' roadway system.