

**BEHAVIOR OF LARGE-SPAN METAL AND
REINFORCED CONCRETE CULVERTS UNDER
EARTH AND LIVE LOADINGS**

BY

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ABSTRACT

Large-span flexible (and rigid) culverts, with spans typically ranging from 3-15m, are a practical structure for water crossings, especially on local road systems, and these soil-structure systems often prove to be an economical alternative to conventional short span bridges. Because of their important applications, these structures need design improvement to withstand earth and live loading.

A collaborative study is being undertaken entitled "**Recommended Specifications for Large-Span Culverts**", funded by the American Association of State Highway and Transportation Officials (**AASHTO**), in cooperation with the Federal Highway Administration (**FHWA**). It is conducted through the National Cooperative Highway Research Program (**NCHRP**), which is administered by the Transportation Research Board (**TRB**). The investigation is being performed by researchers at the University of Western Ontario, the University of Massachusetts at Amherst and consultants at Simpson Gumpertz & Heger Inc. The objective of this overall project is to develop new **AASHTO** design procedures and construction specifications for flexible and rigid large-span culverts, based on the load and resistance factor design (**LRFD**) methodology.

The objective of this study is to develop a simplified design procedure for long span metal and reinforced concrete culverts and to study their behavior under earth and live loadings. The objective is met by conducting an extensive finite element analysis using a two-dimensional elastic-plastic finite element procedure for earth load simulations and three-dimensional finite element analysis for live load calculations. The two-dimensional procedure utilizes a multi-layered structural model to characterize the materially non-linear response of the corrugated metal plate and the three-dimensional

procedure explicitly models the geometry of the vehicle, treating the wheel loads at the end of each axle, and employs a linear elastic soil model. It is a semi-analytic procedure, which uses two-dimensional finite element mesh. The performance of the finite element procedures is examined by conducting a comparison between measured results for two full-scale tests; a low profile metal arch and a reinforced concrete culvert arch.

Predictions for metal culvert deformation and bending moments generated during backfilling and during live loading were excellent using the finite element analysis. Both pre and post-test predictions for deformation and moment successfully captured the culvert response during burial, the impact of backfill soil density and live loading.

Concrete culvert predictions of earth pressures from the finite element analysis were generally close to the field measurements for Test 1 and Test 2. In general, the finite element predictions of stress resultants of the concrete culvert exhibit the same trends as the field measurements, although more measurements at different locations of the culvert would be valuable.

A simplified design method for large span metal culverts has been developed based on the results of a parametric study. Five metal culverts and two reinforced concrete culverts have been examined during the parametric study. Factors such as the influence of soil modulus, culvert shape, culvert span, cover depth and vehicle location were considered during this study. Simplified design equations based on the finite element analysis have been developed to calculate earth and live thrust and moment for metal culverts and earth pressures for concrete culverts.

Keywords: soil-structure interaction, culverts, large-span, limit states, finite element analysis, design, parametric study, corrugated steel, precast concrete, two-dimensional, three-dimensional.