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Developing Load Distribution Formula for Louisiana Cast-in-place Reinforced Concrete Box Culverts

INTRODUCTION

Low load rating factors are often obtained for cast-in-place (CIP) reinforced concrete (RC) box culverts. which is a challenge to bridge engineers nationwide, including in Louisiana. Unacceptable rating factors require intervention measures that may include load posting, strengthening, or even replacement. Bridge engineers must deal with these cases despite the fact that field inspections have revealed no signs of distress in these culverts and that they perform well, which raises a question about current load rating procedures. One option is to use refined methods of structural analysis to overcome this challenge. However, using refined analysis methods on a large inventory of CIP-RC box culverts is a time-consuming burden to bridge engineers. Another option is to conduct live load tests, which is also expensive and time-consuming. This project was initiated to explore the potential for developing a live load distribution formula (LLDF) that produces more consistent results, removes unnecessary conservatism, conforms to safety levels targeted by AASHTO-LRFD BDS, and are suitable for CIP-RC box culverts built using old Louisiana standards.

OBJECTIVE

The primary objective of this project was to investigate live load distribution over buried CIP-RC box culverts for the purpose of recommending the most suitable LLDF that can be used in design and load rating. The goals of the project were to:

1. Conduct a parametric investigation of buried CIP-RC box culverts that covers key parameters known to affect the distribution of wheel loads through the soil onto the culvert's top slab and structurally through the culvert.

2. Analyze results from the parametric study to help evaluate the best LLDF for the design and load rating of CIP-RC box culverts.

3. Study the reliability of CIP-RC box culverts using different LLDF to ensure conformity with AASHTO LRFD BDS.

4. Provide DOTD with recommendations to assist in adoption in the Louisiana *Bridge Design and Evaluation Manual (BDEM).*

SCOPE

The focus of this study is on CIP-RC box culverts buried under low earth fill height (≤ 2 ft.), taking into account the fact that old Louisiana standard details for CIP-RC box culverts provide no resistance to negative moments at the outside top corners of the culverts. CIP-RC box culverts were analyzed for AASHTO-LRFD BDS design axle loads, namely design truck and design tandem loads. One-, two-, and three-barrel culverts with different sizes, slab thicknesses, and concrete strengths were considered in the investigation.

LTRC Report 692

Read online summary or final report:
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METHODOLOGY

A parametric study was conducted considering the key parameters that are known to influence the structural behavior of culverts. The parametric study included 273 CIP-RC box culverts, which were analyzed using refined analysis methods (3-dimensional (3D) finite element (FE) method) to obtain more accurate results that represent actual culvert behavior. Simplified analyses (2-dimensional (2D) finite element (FE) method) often used by engineers were also conducted using several empirical live load distribution formulas. Based on the results from the parametric study, the effects of various parameters on the internal straining actions (forces and moments) were investigated. The key parameters that affect live load distribution were identified, and a live load distribution formula was derived. The main advantage of the proposed formula is that it considers the secondary distribution that occurs in the top slab, which is greatly affected by the wheel load position. Comparisons between AASHTO-LRFD BDS LLDF and the proposed LLDF formula were conducted to study how both formulas conform to AASHTO-LRFD BDS safety level requirements as measured by the reliability index.

CONCLUSIONS

Results from an extensive parametric study considering 273 culvert configurations that cover key parameters that are known to influence culvert behavior. Based on all the results, the following conclusions can be drawn:

1. By comparing results from refined analysis and AASHTO-LRFD BDS, this study confirms that AASHTO-LRFD BDS predictions using current LLDFs are inconsistent, highly conservative for positive moment starting actions, and sometimes unconservative for shear forces and negative moments.

2. Similar conclusions were drawn based on the reliability study results for both AASHTO-LRFD BDS.

3. Using the proposed LLDF formula results in more consistent predictions of straining actions for design and load rating of culverts by removing unnecessary conservatism for positive moment straining actions, M_{pE} and M_{pI}, while at the same time greatly reducing the inconsistency of results for negative moments, V and M_n, and reducing the inconsistency of results for shear forces albeit to a lesser extent.

4. Unlike AASHTO-LRFD BDS LLDF formula which produces a wide range of reliability index, β, values including some cases where β is less than β_{target} of 3.5, all predictions using the proposed LLDF formula meet or exceed this β_{target}, and thus conform to AASHTO-LRFD's target safety level.

RECOMMENDATIONS

Based on the findings of this project, the research team recommends the adoption of the proposed formula (Equation [20]) for distributing the wheel load in the direction perpendicular to traffic, along with AASHTO-LRFD BDS Equation [16] for distributing the wheel load in the longitudinal direction for design and load rating or cast-in-place (CIP) reinforced concrete (RC) box culverts.

$$E=\xi_{SA}(92+1.15H+0.3S) \quad [20]$$

where H is the fill height in inches, S is the barrel span length in inches, and ξ_{SA} is a straining action coefficient equal to 1.0 for positive moment sections, M_{pE} and M_{pI}, and equal to 0.6 for shear and negative moment sections, V and M_n. In the longitudinal direction, it is recommended that the AASHTO-LRFD DBS distribution formula (Equation [16]) be used.

$$E_{span}=L_T+LLDF(H) \quad [16]$$

If load rating of any culverts does not produce acceptable results and load posting would be necessary, it is recommended that refined analyses be used while taking advantage of the modeling recommendations from Project 16-3ST (LTRC Report No. 593).