Role of 3D-Finite Element Modelling in the Analysis of Soil-Structure Interaction Problems

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Engineering design and analysis often rely on simplified models. These models are convenient and practical for use in routine applications. However, they have many inherent limitations. Most significant among these limitations are their inability to model the following: (a) the true non-linear, material behavior, (b) actual construction sequence, (c) dynamic effects of moving traffic loads, (d) the actual 3-dimensional configuration of the structure and (e) 3 dimensional the loading pattern. As a rule, these simplified analysis methods rely on assumptions that are conservative. But sometimes the degree of conservatism can be unacceptably high. This paper describes a research study that used a 3D FEM to find an explanation for apparent disagreement between simplified model predictions for the load rating of highway culverts and results from field inspections of these culverts.

When highway reconstruction projects involve widening or change in elevation of roadways, highway agencies are required to reevaluate existing culverts using AASHTO culvert load rating procedures to verify their structural adequacy. Such reanalysis often indicate that the existing culverts are structurally deficient and therefore must be replaced or retrofitted. However, inspections conducted during replacement of the old culverts show that these structures are in sound structural condition and have no significant distresses. This implied that the existing load rating methods were too conservative and new guidelines were put in place in 2009 based on research conducted by the Texas Tech University.

One key aspect of this research was to understand how soil-structure interaction affects culvert performance and how these effects may be included in the load rating procedure. The revised guide suggested the use finite element (FE) models of different levels of sophistication to help analysts in load rating. Furthermore, the guide states although 2D FE models with simplifying assumptions are acceptable for load rating purposes, they are not capable of predicting the culvert performance completely and recommends the use of 3D models for further research. Hence, this study employed a 3D FE model which simulated the behaviour of the culvert, the surrounding soil and the pavement as one whole unit under the exact 3D wheel load configurations applied in the field testing in an attempt to predict culvert behaviour more accurately. The FE model was built using ANSYS Workbench and allowed for project-specific input values, soil-structure interaction and was equipped with parametric analysis capability.

The 3D FE model was then fed with site specific input parameters determined from detailed site characterization tests. As expected the 3D FE model was able to predict the deformations in the culverts far more accurately than the 2D models. The model was then used to carry out a sensitivity analysis to determine how parameters such as soil and pavement stiffness influenced the structural performance of the culvert.

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