Soil-Structure Interaction of a Reinforced Concrete Arch Culvert

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INTRODUCTION

Culvert structures may be used to convey waterways beneath roadways when the span lengths are short. There are several choices for material and shape of a culvert; in this investigation a cast-in-place reinforced concrete culvert with an arched top and monolithic floor slab is considered.

In this investigation, the provisions of the American Association of State Highway and Transportation Officials (AASHTO) are followed. The live load considered was AASHTO HS 20. The depth of the earth fill over the crown of the culvert was taken to be three feet. A two span continuous structure with clear spans of 20 feet and a clear rise of 10 feet was considered; all elements of the structure were considered to have equal thicknesses of 12 inches.

ANALYSIS

The analyses and design were executed considering a unit wide strip of the structure. The live load supported by this strip was determined as specified in AASHTO for a slab with main reinforcement parallel to traffic. The loads considered were

- dead load of the structure
- dead load of earth fill above the structure
- lateral earth pressure
- vehicular live load

The soil adjacent to the structure was assumed to be granular with a unit weight of 120 lb/ft^3 and an angle of internal friction of 30 degrees. Additionally, the concrete strength was taken to be 4,000 psi and the yield strength of the reinforcing steel to be 60,000 psi.

The arch had radius of 40 feet in the central portion and radii of 4 feet at its ends; for a 10 foot clear rise, the vertical walls are approximately 4.5 feet tall. Primary flexural reinforcing was parallel to the span of the arches; shrinkage and temperature (distribution) reinforcing was normal to the primary flexural reinforcing. Two mats of reinforcement were used in all elements of the structure.

It was assumed that the soil adjacent to the structure was placed in lifts and compacted with hand-operated equipment until the earth fill was 2 feet above the crowns of the arches. It was further assumed that this compaction resulted in the soil adjacent to the structure being in the at-rest state. Then, as the sidewalls deflect into the adjacent soil, the soil moves toward the passive state. The associated lateral earth pressure distribution is dependent upon the magnitude of the wall deflection into the soil.

The culvert structure was assumed to be supported on an elastic subgrade and modelled using linear springs at nodes in the finite element idealization. The vertical modulus of subgrade reaction was taken to be 250 lb/in^3. This idealizes the bottom slab as a beam on an elastic foundation.

RESULTS

The bending moments and shear forces at critical locations were determined. Then, the flexural reinforcing was calculated and the shear check to determine whether shear reinforcing was necessary. The live load deflection was checked with the AASHTO deflection criterion. Additionally, the crack control provisions as well as the fatigue considerations of AASHTO were checked.

Finally, the AASHTO optional procedure for checking internal forces associated with active and passive lateral earth pressures was compared to the soil-structure interaction approach.