Numerical Modeling of Buried Pipe under Wheel Loads Using FLAC 3D

Hamed Niroumand, Department of Geotechnical Engineering, Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai, Malaysia
Khairul Anuar Kassim, Department of Geotechnical Engineering, Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai, Malaysia
Behnam Adhami, Department of Civil Engineering, Faculty of Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran

ABSTRACT

A steel pipe is buried at a shallow depth beneath a roadway. The behavior of steel pipe during wheel load was studied in this paper by FLAC 3D. An analysis is needed to evaluate the effect of wheel loading on the road surface deflection and pipe deformation. The top of the pipe is 1.5m beneath the road surface. The pipe has an outer diameter of 4m and is 0.12m thick. The pipe excavation is 15m wide and 6m depth. The steel pipe is placed on a 0.4m thick layer of soil backfill, and then soil is compacted around the steel pipe. The wheel load is increased during failure occurs in the soil. Soil backfill behavior has been considered with Mohr-Coulomb Model in analysis. The analysis defines the failure load and the resulting soil and pipe displacement.

Keywords: FLAC 3D, Mohr-Coulomb Model, Numerical Modeling, Soil Displacement, Soil Envelope

1. INTRODUCTION

Predictability of a structural design’s performance is one of many important aims of structural analysis. Elastic analysis of structures requires that very specific conditions at all points within the structure and on its boundary are satisfied. Action and reaction forces must be in equilibrium, deformations of adjacent points within and on the boundaries of a structural element must be compatible, and only appropriate stress-strain laws may be employed. To enhance performance, structures and structural elements are often designed as composites of multiple materials. The buried pipe-soil structural composite requires properly selected and compacted soils surrounding the pipe to reinforce it in a manner that favorably minimizes the pipe’s bending stress and maximizes ring compression. It is the performance of the pipe-soil composite structure that must be predicted by engineering design.

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A steel pipe is buried at a shallow depth beneath a roadway. An analysis is required to evaluate the effect of wheel loading on the deformation at the road surface, the deflection and stresses in the pipe. For unburied or unsupported pipes of elastic materials, and for unburied or unsupported pipes of plastic materials, at the instant of load application as shown in Figure 1, the relationship between load and deflection is given by:

\[ \text{Load} \times \text{Deflection} = \text{Constant} \]

2. INTERACTION OF A SOIL ENVELOPE WITH A FLEXIBLE PIPE

Flexibility of buried pipes is a desired attribute. A buried pipe and its adjacent soil elements will attract earth embankment loads and live loads in accordance with a fundamental principle of structural analysis: stiffer elements will attract greater proportions of shared load than those that are more flexible.

This principle is illustrated in Figure 2 where, given the same well-compacted soils surrounding the pipe, the more flexible pipe attracts less crown load than the rigid pipe of the same outer geometry. The surrounding soil is of greater stiffness than the flexible pipe and of lesser stiffness than the rigid pipe.

3. NUMERICAL MODELS

3.1 Problem Statement

The top of the pipe is 1.5m beneath the road surface. The pipe has an outer diameter of 4m and is 0.12m thick. The pipe excavation is 15m wide and 6m deep. The pipe is situated on a 0.4m-thick layer of soil back fill, and then soil is compacted around the pipe. The wheel load is applied to four grid points on the surface. If the load is assumed to be carried by \( \frac{1}{2} \) of each zone connected to the grid points, then the wheel area can be assumed to be 1.275m. The wheel load is increased until failure mechanism occurs in the soil. The analysis determines the failure load and the resulting soil settlement, pipe displacement and stresses.
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