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Immediate Settlement of Ring Footings Resting on Inhomogeneous Finite Stratum

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Abstract: This paper describes the immediate settlement of uniformly loaded rough ring footings with any stiffness on an inhomogeneous finite layer overlying a rough rigid base, which is not yet covered in the literature. Numerical solutions for a wide range of geometric and material combinations are obtained by finite element method. The effects of dimensionless parameters related to footing internal opening, compressibility, footing stiffness, finite layer thickness and soil inhomogeneity are examined. Based on the results, design charts are presented in the form of settlement influence factors that can be used to calculate the immediate settlements at the inner and outer points of ring footings.

Keywords: ring footing; settlement; finite element method; elasticity; inhomogeneity

1. Introduction

Ring footings are continuous footings that have been wrapped into a circle. In engineering practice, they are commonly used to support columns or walls of axisymmetric structures such as silos, smokestacks, television antennas, communication towers, and bridge piers [1]. Ring footings with internal openings can reduce the material volume required for their construction, providing a more cost-effective design. Additionally, the ring footing has an increase in overturning stability when compared to a solid circular footing with the same area [2]. However, the contents of special structures (e.g., liquid storage tanks) are spread evenly across the total base area, and this weight is probably greater than that of the tank itself. Therefore, the response of tanks is considered to be a solid circular footing with diameters equal to the diameter of the tank [3]. The behavioral characteristics of ring footings interacting with supporting medium are dependent on the soil and loading conditions, as well as the geometry of these opening. For the realistic design of ring footings, it is essential to understand their settlement and bearing capacity.

The immediate and consolidation settlement checks are an important part of footing design. Immediate settlement is caused either by the undrained distortion of clay beneath the footings, or the drained settlement of footings on sand [4]. In general, the immediate settlement of footings on clay is small when compared with consolidation settlement. However, it may be significant, especially for highly plastic clays or organic soils. Immediate settlement is also termed elastic settlement, because it is usually calculated from the theory of elasticity using the linearly elastic soil models [5].

Several studies have been conducted to predict the immediate settlement of footings with various shapes (e.g., strip, rectangular, square and circular footings). This has been done by using the integral transform technique, semi-analytical procedures, the finite element method and the boundary element approach [4,6–8]. In contrast, the available investigations on immediate settlement of ring footings are few. For example, Fisher [9] presented a theoretical formulation for the elastic settlements under uniformly loaded flexible footings resting on a homogeneous isotropic elastic half-space by