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EFFECT OF AREA REPLACEMENT RATIO ON CONSOLIDATION SETTLEMENT OF FLOATING STONE COLUMN IN SOFT SOIL

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ABSTRACT

Soft clay soils present significant challenges in construction due to their low bearing capacity and high compressibility. While stone columns are commonly used to improve such soils, floating stone columns are less favored due to the complexity of predicting consolidation behavior, particularly with double-layered conditions. Limited experimental research using unit cell idealization exists to support numerical validation for floating columns, and the accuracy of settlement prediction in untreated zones remains unclear. This study investigates the effect of area replacement ratio (α = 0.10 - 0.33) on the consolidation behavior of floating stone columns using laboratory model tests and numerical simulations. Unit cell idealization was employed to assess settlement, excess pore water pressure, and stress concentration ratio, with floating columns (H_c = 160 mm and 320 mm) and end-bearing columns (H_c = 400 mm) embedded in soft kaolin clay under vertical loading. Results showed that increasing α reduced settlement by up to 70%, accelerated consolidation by up to 96%, and increased stress concentration ratio from 2.1 to 5.0. Although numerical analysis slightly overestimated early-stage settlement, it showed reasonable agreement with experimental results. A new design method was developed to estimate the settlement improvement factor and stress concentration ratio for floating stone columns, and it demonstrated good agreement with existing models, offering improved reliability for design applications.

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INTRODUCTION

1.1 Research background

Soft soil creates significant challenges in construction due to its low shear strength, high compressibility, and slow consolidation behaviour. These characteristics often lead to problems such as excessive settlement, poor load-bearing performance, and instability during and after construction (Mohamad et al., 2016). In Malaysia, such conditions are common in coastal regions, reclaimed lands, and riverbanks where soft marine clays are widespread (Zhou et al., 2023). The high-water content and low permeability of soft soil slow down the dissipation of excess pore water pressure, thereby prolonging consolidation and increasing the risk of long-term settlement (Idrus et al., 2023).

To mitigate these issues, various ground improvement techniques have been adopted, including preloading, vacuum consolidation, deep mixing, and stone columns. Among these, stone columns are one of the most commonly used solutions due to their dual role in improving shear strength and accelerating drainage. Stone columns are constructed by inserting compacted gravel or crushed stone vertically into the soil, enhancing the composite stiffness and offering radial drainage paths to facilitate faster consolidation (Ali et al., 2022).

There are two primary types of stone columns: end-bearing and floating. End-bearing columns extend through soft layers to rest on a firm stratum, effectively transferring structural loads to stronger ground. However, this approach can be limited by economic and practical constraints, especially when dealing with deep soft layers. In such conditions, achieving penetration to hard stratum becomes challenging, making installation costly or infeasible. Floating stone columns, on the other hand, are terminated within the soft soil layer and rely on the improved composite behaviour of the soil-column system rather than direct end support (Ng, 2018).