COMPARATIVE FINITE ELEMENT ANALYSIS OF SUNK WELLS LOWERING IN VARYING SOIL

Anna Szymczak-Graczyk*,[a], Tomasz Garbowski[b]

[a] Poznan University of Life Science, Poland anna.szymczak-graczyk@up.poznan.pl;
[b] Poznan University of Life Science, Poland tomasz.garbowski@up.poznan.pl

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1. INTRODUCTION

The design and construction of sunk wells for civil and environmental infrastructure projects—such as stormwater systems, tunnels, and foundations—demand a careful assessment of interactions between structural elements [1,2] and the surrounding ground environment. These challenges are amplified when construction is conducted in heterogeneous or saturated soils [6-8]. Unpredictable soil reactions, buoyancy effects, and uneven stress distributions can compromise the sunk well's structural integrity if not adequately addressed. While full-scale field testing is rarely feasible in the early design stages, numerical modeling offers a powerful tool for simulating performance under variable loading and environmental conditions.

In practical engineering, it is rarely feasible to assess all possible geotechnical scenarios through field testing [4]. Instead, numerical simulations offer a valuable tool [3,5] to test multiple design configurations, evaluate risk factors, and identify vulnerable loading conditions that may result in structural failure. In the case of sunk well construction, it is particularly important to understand how different depths, groundwater levels, and surrounding soil compositions influence internal stress distributions in the sunk well.

2. METHODS AND MATERIALS

This study investigates the behavior during lowering of a reinforced concrete sunk well during lowering under diverse soil conditions using a custom-built axisymmetric finite element model implemented in MATLAB. The sunk well, with an internal diameter of 6 meters, a depth of 6 meters, and a wall thickness of 30 cm, is reinforced on both faces with a mesh of ϕ12 bars spaced every 15 cm. The model simulates the stepwise lowering of the sunk well into the ground. While the surrounding soil is not explicitly modeled using continuum mechanics, its effects are introduced through external loading: self-weight of the sunk well, lateral earth pressure, hydrostatic water pressure (in selected cases), and frictional interaction along the sunk well-soil interface.

Several dozen configurations were evaluated, including dry and saturated conditions, multi-layered soil profiles, and variations in groundwater levels. For each variant, lateral pressure and base uplift due to buoyancy were applied using analytical expressions. The mechanical response of the sunk well was analyzed at each depth increment, with focus on stress distributions and the identification of critical zones of tensile and compressive stresses. Particular attention was paid to the most unfavorable configurations potentially leading to cracking or structural instability.

In the absence of an explicitly modeled soil continuum, the following formulas were used to define the loads:

- lateral earth pressure (active): $\sigma_h = K_a \cdot \gamma \cdot h$
- base uplift pressure (in presence of groundwater): $p_w = \gamma_w \cdot h_w$

- frictional force on sunk well sidewall: $F_f = \mu \cdot \sigma_v \cdot A_{contact}$

Where:

- γ is the unit weight of soil,
- γ_w is the unit weight of water,
- h is the current embedment depth,
- h_w is the water table level below the ground surface,
- μ is the friction coefficient,
- K_a is the active earth pressure coefficient.

Boundary conditions were adjusted dynamically during sunk well sinking, simulating the progressive exposure to increased loading. Frictional forces and earth pressure were applied as surface loads.

3. PRELIMINARY FINDINGS

- The most unfavorable stress states occurred in highly stratified soils with soft interlayers and high groundwater levels.
- Dry, dense sand yielded the most favorable configurations in terms of uniform sunk well during lowering and low stress peaks.
- Groundwater significantly contributed to uplift pressure, particularly in the initial stages of sunk well embedment, emphasizing the need for buoyancy-resistant design.

These findings provide valuable guidance for the design and execution of sunk well sinking projects in complex geotechnical settings.

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