

PhD Thesis, titled

Pile Response in Jointed Rocks Under Combined Vertical and Lateral Loading

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ABSTRACT

Rock-socketed piles are widely adopted as deep foundation elements in geotechnical engineering due to their ability to transfer heavy structural loads through weak overburden soils into competent rock. Their performance is influenced by rock mass conditions/joint characteristics, socket geometry, and construction-induced effects such as sediment deposition at the pile-rock interface. A comprehensive understanding of these factors is essential for safe and economical foundation design, particularly under combined axial and lateral loading.

This study investigates the behaviour of rock-socketed piles through an integrated approach combining laboratory model tests and numerical simulations using Plaxis 3D. Experimental work was conducted on model piles installed in synthetic rock blocks representing weak rock conditions. The intact synthetic rock material had uniaxial compressive strengths of 5 MPa and 8 MPa, while jointed rock conditions were simulated by introducing predefined discontinuities. The study considered two socket length-to-diameter ratios ($L/D = 3$ and 5) to investigate pile behaviour under different rock conditions. Additional tests examined the influence of drilling-induced sediments of varying thickness at the pile toe/base. The results demonstrate that pile performance is governed by a complex interplay of rock strength, pile length-to-diameter ratio, joint roughness, and sediment conditions. Stronger rock and longer sockets generally enhance

axial and lateral resistance, though the efficiency of increased length is limited in weaker rocks due to incomplete mobilisation of shaft resistance. Jointed rock conditions influence pile behaviour by altering load transfer mechanisms, in which shear mobilisation along joint planes contributes to load resistance while simultaneously reducing overall stiffness and altering moment distribution under combined loading. Sediment at the pile toe/base was found to affect the pile response. Interestingly, thin sediment layers showed reduced settlement due to micro-concrete penetration and hardening.

Numerical simulations complemented the experimental findings, validating observed load-displacement trends and enabling parametric studies beyond the scope of physical testing. The simulations revealed that axial capacity is highly sensitive to sediment at shorter socket lengths, where end bearing dominates, but becomes governed by side friction at greater depths, with marginal gains beyond this length. Lateral response under combined loading showed notable improvement for shorter sockets, but the axial contribution diminished with depth, and for deeper sockets, lateral capacity was largely governed by pile-rock interaction alone.

Overall, the study establishes that rock-socketed pile behaviour is strongly influenced by the interaction between socket length, rock conditions, joint properties, and loading type. Independent loading tests tend to overestimate field performance, while combined loading provides a more realistic and conservative estimate. The findings have direct implications for the design of pile foundations in jointed and sediment-influenced rock masses, highlighting the need to account for socket length, joint orientation, and sediment effects in practice. This work provides a systematic framework for understanding pile-rock interaction and offers guidance for optimising deep foundation design in complex geological conditions.