

## ABSTRACT

The interaction of two different types of materials at their interface in a geotechnical engineering structure can be complex and can profoundly influence the efficiency and stability of the system. Gaining an understanding of the frictional behaviour at these interfaces is crucial for the design of safe and efficient structures, as well as for optimising the properties of interface materials in practical applications. Recent advancements in bio-inspired geotechnics have shown promise in developing innovative engineering surfaces for various geotechnical applications. Of particular interest is the distinctive direction-dependent frictional characteristics, termed frictional anisotropy, of the ventral scale patterns of the snakeskin.

This thesis aims to investigate the shear behaviour of the snakeskin-inspired surfaces that can exhibit optimal frictional characteristics required in geotechnical applications. For this purpose, ventral scale morphologies of different snakes were studied, and three model organisms, namely Viper Snake (VS), Eastern Kingsnake (EK) and Sand Boa (SB), that move over different terrains and exhibit different locomotion techniques were selected. The selected scale patterns were idealised from a geotechnical engineering perspective, and continuum surfaces with the selected patterns were 3D printed using a Fused Filament Fabrication (FFF) 3D printer. A systematic investigation of the interface shear behaviour of the developed snakeskin-inspired continuum surfaces with different geomaterials, including sands of different shape characteristics, clay and Plaster of Paris (PoP), was undertaken. To this end, a versatile interface shear test apparatus was developed to understand the interface shear behaviour accurately.

The interface shear tests on the sands of different shapes (angular sand and rounded glass beads) revealed that the snakeskin-inspired patterns exhibit significantly different behaviour than the unpatterned surface and a prominent frictional anisotropy between the cranial (scales oriented towards the head of the snakes) and the caudal (scales oriented towards the tail of the snakes) directions of shearing. It was also observed that the frictional anisotropy and the efficiency of the snakeskin-inspired patterns depend on the morphology of the scale patterns, namely, the height and the shape of the patterns and the shape of the sand particles. The SB patterns mobilised larger frictional resistances and frictional anisotropy, followed by EK and VS.

The shapes of the different snakeskin-inspired patterns were further adopted for ribbed 3D printed continuum surfaces to exclusively understand their effect on the complex interactions at the interface, and their shear behaviour was tested with sand and clay soils. The results of the tests show that the shape of the snakeskin-inspired ribs is also an influential parameter in mobilising their frictional anisotropy with soils and that they generate considerable inhomogeneous deformation at both sand and clay interfaces. Both snakeskin-inspired scale asperities and the ribs mobilise interface friction resistances greater than the shear strength of the sands in the cranial direction, whereas the clay-ribbed interfaces exhibited higher interface shear resistance than the shear strength of the clay in the cranial and caudal directions due to the complex interactions at the interface. It was also revealed that the snakeskin-inspired patterns perform better for applications involving low normal stresses.

The concept of the frictionally anisotropic behaviour of the snakeskin-inspired patterns with a solid or continuum geomaterial (PoP) was explored for the first time through interface shear tests. The results indicated that the frictional anisotropy of the snakeskin-inspired patterns is in-

deed mobilised by solid or continuum materials, which can be attributed to the more wearing of the PoP surfaces in the cranial direction than the caudal directions. The frictional anisotropy of the snakeskin-inspired patterns was found to be dependent on the scale angle of the patterns and showed an increase upto a critical scale angle of  $14.5^\circ$ , which was followed by a decreasing frictional anisotropy with an increase in the scale angle. Based on the encouraging results from the interface shear tests, Split Sets with snakeskin-inspired surface patterns were 3D printed to explore their application for frictionally anisotropic friction bolts. The insertion and pull-out model tests on the snakeskin-inspired Split Sets with PoP blocks also bring out a frictional anisotropy of the patterns, which follow a bilinear relationship with scale angle, with the least occurring at  $16^\circ$ .

The findings of the study are encouraging for potential applications in geotechnical engineering. The significant data generated in the study to understand the fundamental behaviour of snakeskin-inspired patterns with different geomaterials is a valuable addition to the emerging domain of bio-inspired geotechnics and lays a strong foundation for future studies and research.