IP – M3G

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Title of PhD subject: Behaviour of superficial soils under vertical, lateral and cyclic loadings

Summary:

Photovoltaic energy is experiencing strong growth due to its alignment with current sustainable development challenges. We are witnessing the emergence of technological solutions associated with the installation of solar panels in various situations (building façades, rooftop covers, parking canopies, pergolas), with the objective always being to "optimize" a sun-exposed space that serves an additional function (often as a shelter). Among the different solutions, the development of photovoltaic fields is gaining traction, allowing rural areas to be repurposed in two main ways: either by providing a secondary function alongside its primary use as pastureland or by utilizing low-value areas (former polluted sites, industrial sites, or nutrient-poor land). In the latter case, solar panels cover the entire available space. These structures are anchored to the natural ground using monopod or bipod (portal frame) foundations. The loads transmitted are relatively light compared to typical building loads, but these structures are subjected to significant horizontal and vertical tensile loads due to wind action and the large span of the panels.

While the behaviour of foundations (especially piles) under compression is well understood from both a scientific and regulatory perspective, their response under tension and bending—particularly under cyclic loading—remains less well-documented. Research is being conducted on this topic for wind turbine stability, but in the case of photovoltaic power plants, specific studies are needed. This is because the foundations of these structures are often slender and embedded at shallow depths (approximately 1.5m) in generally poor and heterogeneous soils. The mechanical behaviour of these superficial soils under lateral and/or tensile loading presents a significant scientific challenge: current geotechnical practice generally neglects its contribution to the resistance of piles, due to its high level of uncertainty.

Moreover, the large scale of these photovoltaic power plants, which extend over several hectares, raises questions about the impact of the variability of geotechnical soil properties on the mechanical behaviour of the foundations. The design principles and knowledge associated with deep foundations are not easily applicable in this case due to the limited height of the foundations and the vast expanse of the land.

The objectives of this study are twofold:
1- First, to determine the behaviour of these superficial soils (in terms of resistance and modulus) based on the applied constraints (lateral and tensile).
2- Second, to reveal the impact of geotechnical variability on the mechanical behaviour of these soils.

Initially, this study will examine the effects of foundation shape, size, and soil type on stress distribution within the soil mass under different loading conditions (tensile and lateral loading, combined shear-tensile loading, unidirectional or cyclic). The research will begin with numerical modelling using discrete element methods to determine these stress distributions. Then, small-scale experimental tests will be conducted on foundation models of a few centimetres in diameter, placed in different soil types. Finally, full-scale experimental tests will be carried out in a 3-meter-deep geotechnical test pit on a driven foundation model embedded in a soil mass. The experimental results will be compared with numerical modelling.

Subsequently, the study will investigate the effect of geotechnical variability on the mechanical behaviour of these foundations. A reliability-based approach will be proposed, incorporating the developed numerical models along with variable geotechnical parameters in three dimensions to account for the natural heterogeneity of the soil.