Abstract

The subject of this dissertation is the investigation of unsaturated soils, with particular emphasis on their susceptibility to cracking and on methods for mitigating this phenomenon through modification of soil composition. The tested soil was amended with montmorillonite to increase its cracking susceptibility, as well as with additives enhancing resistance to crack formation, including polypropylene fibers, natural jute fibers, recycled PET fibers, waste glass fibers laminated with polyester resin, cement, and waste granodiorite dust. The objectives of the study included the determination of mechanical parameters of soil mixtures, reliability analysis of the ultimate bearing capacity of shallow foundations subsoil, assessment of the influence of additives on the soil cracking potential, and the development of tools for predicting crack intensity and spacing.

The study comprised two interrelated stages: experimental and analytical. In the experimental part, shear and compressive strength tests were performed, and matric suction was determined using the filter paper method. The cracking process during drying was also investigated at the specimen surface using digital image analysis. In addition, the internal structure of the specimens was examined using X-ray computed tomography. The results demonstrated that the addition of fibers and cement significantly increases the cohesion and internal friction angle of the soil mixtures. Moreover, natural and recycled fibers were shown to provide soil reinforcement comparable to that achieved with synthetic fibers.

The analytical part of the dissertation is based on three components. The first is a predictive model of crack intensity developed using machine learning techniques (random forest), which enabled the identification of the most influential parameters governing soil cracking potential. The second component is a reliability analysis of subsoil bearing capacity beneath shallow foundations performed using the random set method. This approach was shown to effectively account for uncertainty in geotechnical parameters and to support safe foundation design. The final component is a numerical model of crack development based on the finite element method, which accurately reproduces crack spacing in comparison with experimental observations.

The novelty of the dissertation consists in the interdisciplinary integration of geotechnical engineering with data analysis and probabilistic methods, as well as in the application of solutions consistent with sustainable development principles, such as the use of waste materials and natural fibers. The obtained results have direct implications for engineering practice in the design of safe earth structures and shallow foundation subsoil.

Piotr Wyborski