Master Thesis / Masterarbeit

Topic:

Development and validation of an optimization tool for the calibration of the parameters of advanced constitutive models using Genetic Algorithms

Description:

The process of calibrating material parameters from laboratory tests in geotechnical engineering for the use in numerical simulations (e.g. serviceability and ultimate limit state analyses) can often be very subjective, depending heavily on the experience and knowledge of the engineer. Some calibration tools exist; however, these often require significant input and fine-tuning from the user and are able to calibrate only some of the parameters. Additionally these tools often result in ill conditioned material parameters due to influences such as: (1) the inherent variability of the state and properties of the soil, (2) variations in sampling methods, (3) variations in specimen preparation and testing itself, and (4) machine measurement errors when performing tests - all contributing to an uncertain soil response. Instead, the engineer is forced to perform a tedious manual calibration of the material, consisting of estimating parameters and iteratively, performing simulations, plotting the simulated test results with the experimental data and visually judging the suitability of the selected parameters.

In order to improve not only the efficiency of the calibration process and to establish an objective framework for the selection of the 'best-fit' parameters including upper and lower bounds of the expected behaviour of the soil an optimization tool based on the Genetic Algorithm has been developed in Python and applied on the constitutive model Hypoplasticity (NIEMUNIS, 2003 or HERLE, 1997). This tool enables the automatic calibration of constitutive material parameters (Fig. 1 a) based on monotonic laboratory investigation results (e.g. Odometer, Triaxial tests etc.). Furthermore, a methodology was developed for treating uncertain experiments showing at times contradictory mechanical behaviour as well as considering the inability of material models to describe accurately all aspects of the mechanical behaviour of soil. The potential of this tool has been well demonstrated for the relatively simple case of monotonic loading under drained conditions, however the unloading/reloading and even cyclic behaviour cannot be considered with the current formulation.

The goal of this scientific work will be the further development of this calibration tool to consider experimental results with unloading reloading stress paths as well as cyclic loading under both drained and undrained conditions. Additionally more complex material models shall be considered for various types of soil behaviour to demonstrate the capabilities of the tool (e.g. MAŠIN, 2014 or NIEMUNIS et. al. 2009 for fine-grained anisotropic soils, and FUENTES ET. AL., 2020 or GRANDAS TAVERA et. al., 2019 for cyclic behaviour of sands). A secondary objective is, in order to reduce the computational time and the usability of the tool, the translation of the code into the programming language Fortran to enable the direct embedment into the open source element-testing tool Incremental Driver (NIEMUNIS, 2007 & 2014) used to perform the simulations. An example of the typical behaviour of soil inclined to liquefaction under cyclic loading and the simulation using manually calibrated parameters is depicted below (Fig. 1 b).

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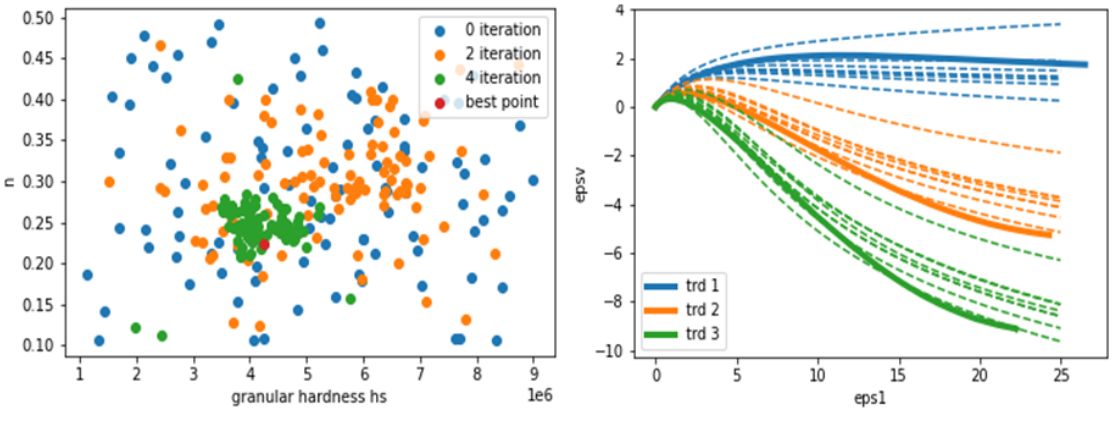
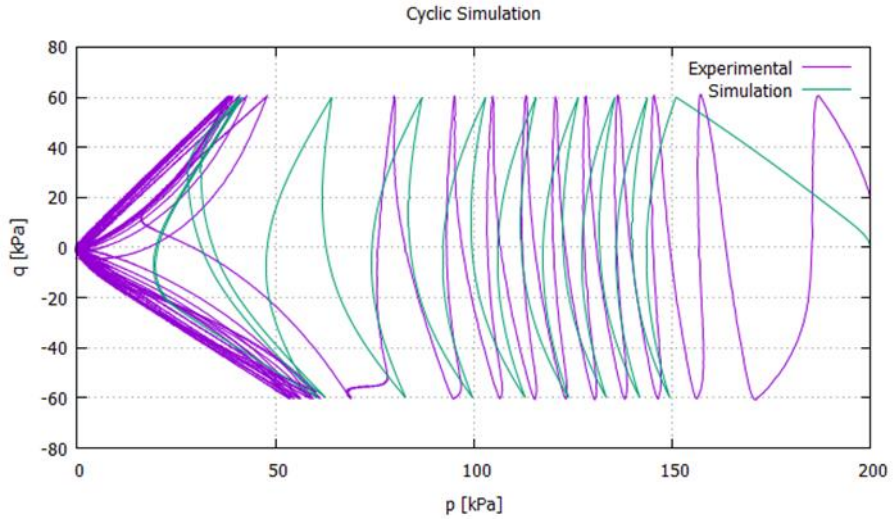


(a)



(b)

Figure 1: (a) Results of the optimization tool using laboratory results conducted on Karlsruhe Sand and (b) the simulation of cyclic loading for the study of the liquefaction behaviour of soil

Scope of work:

1. Understanding, validation and optimization of the existing optimization tool (e.g. under monotonic undrained conditions)
2. Development of a framework for optimizing the material parameters based on experimental results with cyclic unloading and reloading stress paths under both drained and undrained conditions
3. Application of the model to calibrate the parameters of at least three advanced material models

Prerequisites:

- Good understanding of the mechanical behaviour of soils
- Knowledge of at least one programming language

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Ausgegeben an:

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Literatur

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