

Groundhog - A general-purpose geotechnical Python package

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Summary

Geotechnical engineering is an engineering discipline in which the mechanical behaviour of soil and its impact on the performance of foundations is studied. Because of the complex constitutive behaviour of soil and the large variation in mineralogy, geological origins, stress conditions and foundation types, there is no generally applicable theory for soil behaviour and foundation design. Instead, myriad semi-empirical models and parameter correlations have been developed to describe the mechanical behaviour of soils and foundations (Budhu, 2010). The Python package Groundhog was developed to enable the efficient use of these formulae in geotechnical engineering education, research and practice.

Statement of need

Groundhog is a Python package for geotechnical engineering calculations. The soil parameter correlations and foundation design models which are used in this discipline are scattered across various resources (textbooks, journal articles, recommended practices) and engineers spend a significant amount of time implementing them in calculation tools (typically Microsoft Excel). This is not an ideal situation, with a lot of repeated work and implementation mistakes often going undetected. Moreover, certain geotechnical calculations are calibrated for specific ranges of the input parameters. Checking that the inputs are within these ranges is often omitted in an Excel implementation.

To overcome these shortcomings, Groundhog provides a robust implementation of geotechnical functions with in-built parameter validation and [extensive documentation](#). Each input parameter is described, providing the expected units and the default validation range. The validation ranges can be overridden by the user with specific keyword arguments, making adjustments to the validation ranges explicitly visible.

Because geotechnical functions can return multiple outputs (e.g. intermediate calculation results), the output of Groundhog functions are Python dictionaries. The users can select the relevant outputs for their calculations by addressing the appropriate dictionary key. Groundhog functions are also unit-tested to ensure they return the expected results.

In addition to geotechnical functions, selected geotechnical workflows are encoded in an object-oriented manner. Processing of data from the cone penetration test (CPT) and the standard penetration tests (SPT) is a recurring task and the steps in the processing workflow are implemented in the PCPTProcessing and SPTProcessing classes respectively. The manipulation of stratigraphic profiles, which describe the various layers in the subsoil, is made possible with the SoilProfile class. Soil parameter visualisation and interactive parameter selection is made possible in the LogPlot class (using the Plotly ([Inc., 2015](#)) plotting backend) and the LogPlotMatplotlib class (using Matplotlib ([Hunter, 2007](#)) as plotting backend).

The package implements various methods for basic foundation design taught in undergraduate and graduate courses (e.g. shallow foundation capacity on sand and clay, axial pile resistance in sand clay, one-dimensional consolidation).

Groundhog is under continuous development and allows the geotechnical community to focus on a single robust and well-documented set of calculation tools.

Applications in research

The geotechnical parameter correlations and geotechnical workflow automation tools have enabled research in offshore wind geotechnical engineering on the following topics:

- Natural frequency analysis of offshore wind turbine structures across an entire offshore wind farm (Fallais et al., 2022). Groundhog was used to define the stratigraphic profiles and perform the geotechnical parameter selection. The automation offered by Groundhog allowed all data to be processed in a reasonable time and with a focus on quality.
- Back-analysis of bending moment measurements on offshore wind turbine monopiles (Stuyts, Weijtjens, Jurado, & Devriendt, 2024). Groundhog was used to define the stratigraphic profiles and perform the geotechnical parameter selection.
- Evaluation of CPT-based correlations for shear wave velocity estimation for North Sea soils (Stuyts, Weijtjens, Jurado, Devriendt, & Kheffache, 2024). All correlations evaluated in the study were implemented in Groundhog and a newly developed correlation was shared with the community through implementation in the package.
- Groundhog is also being used in research on seismic inversion. Amplitude vs Offset (AVO) inversion allows inversion for bulk modulus, shear modulus and density. Groundtruth geotechnical data is processed with Groundhog and where direct measurements of the parameters are not available, the package is used to estimate them from other data sources.

Applications in geotechnical engineering education

Groundhog is being used in undergraduate and graduate courses at Ghent University. By providing a parametric and well-documented implementation of geotechnical correlations, the package allows students to spend more time on the parameter selection process and get more insight into the underlying data for these semi-empirical correlations. The effect of parameter variations can also easily be studied while reducing the time spent on implementing equations.

A dedicated two-day training course has also been set up to teach Python and Groundhog to geotechnical engineers seeking to get started with scripting. This course has been delivered to Systra in Dubai (April 2024) and RINA in Milan (October 2024).

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