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Ground Model Workflow with DAARWIN

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ABSTRACT

Structural geological models are used to understand and visualize how geological materials are organized below the Earth surface. This technique is crucial in different fields of geomechanics such as mining to identify mineral deposits and to plan mining operations, environmental engineering to assess the contamination of soil and groundwater and to design remediation strategies, and civil engineering to design foundations, tunnels and other underground structures. In this sense, ground models allow the engineer to understand and to visualize the spatial organization of subsurface geological structures and, additionally, it is possible to evaluate the spatial distribution of material properties which is essential in any geomechanical study prior to any project.

In this context, SAALG Geomechanics through DAARWIN web platform provides a suitable software tool for the geotechnical engineer to perform the complete ground model workflow. The process starts introducing borehole data from different sources and then, the engineer can visualize and interpret borehole logs, define geomechanical units and assign parameters from in-situ and laboratory tests, as well as assign units' geometry from geological layers. Finally, the user can feed this information to the system to obtain a 2D cross-section, that can be exported to the commercial Finite Element software PLAXIS and use this PLAXIS model for geotechnical design and more advanced analyses such as Sensitivity analysis and Back-Analysis, which are also implemented in DAARWIN.

Keywords: Ground Model; DAARWIN; 2D Cross-section generator; Geotechnical models

1. Introduction

Ground modelling is an important tool in geotechnical engineering. The evaluation of the spatial distribution of properties throughout the subsurface plays an essential role in a wide range of engineering applications, from scientific investigations of geological/geotechnical aspects (Culshaw 2005), hydrogeological investigations (Anderson 1989), raw materials and hydrocarbons (Ringrose et al. 2015), to policy and public hazard information.

In this context, a general ground model workflow has recently been developed by SAALG Geomechanics and implemented within the DAARWIN web platform, which was initially conceived to drive the workflow of real-time Back-Analysis during construction as described in Acosta et al. 2023. The ground model workflow consists of several steps such as:

- Acquisition, storage, and visualization of factual borehole data from the project's ground investigation and capability to select boreholes to generate the ground model.
- Engineer's interpretation of the borehole logs and assignment of geological layers into geo- technical units.
- Geotechnical characterization of the units considering the data obtained from in-situ and laboratory tests.
- Generation of the 2D Cross-section (proposal).

The functionalities described by the first and sec- ond items of the general ground model workflow are already implemented in the DAARWIN web platform and deployed within production while the third and fourth items are currently under development. Advancing towards the ultimate objective of providing an integrated tool for managing ground information and generating ground models, the geotechnical characterization of geotechnical units (third item) is currently performed manually is not included in this article. However, progress achieved in the 2D cross-section proposal (fourth item) is presented instead.

This paper aims to describe the procedure proposed to obtain the 2D cross-section that allows the engineer to understand and visualize the spatial organization of the geological structures underneath the area of interest. At the current stage of development, cross-section is generated in PLAXIS using the PLAXIS API (Application Programming Interface) instructions and then, an independent generator will be proposed, which will provide the cross-section within DAARWIN. In fact, the procedure proposed in this article provides an output file whose data structure is organized in such a way that provides the coordinates of the points that make up the polygons of each geological unit. Thus, the sections can be easily viewed within the DAARWIN web platform.

As mentioned in the description of the ground model workflow, a cross-section generator requires a certain amount of initial information provided by the borehole distribution in the study area and borehole data. Once the borehole logs have been interpreted and the different geological units have been identified in each borehole, an overview of the distribution of the geological units may be examined considering a side-by-side visualization of all the boreholes selected for the ground model. On this basis, the methodology developed to generate the 2D cross- sections is based on the analysis of geological unit contacts in a certain borehole and their evolution along the boreholes selected to perform the ground model.

2. Methodology

The 2D cross-section generator is designed to fulfill a twofold objective: i) to build the geotechnical profile directly in PLAXIS as a first step of the corresponding Finite Element model that the engineer will use for geotechnical design calculations and ii) to obtain a geotechnical profile to be represented within DAARWIN web platform and then exported using a standardized exchange format, which will not involve PLAXIS software suite. In both functionalities, a procedure based on the analysis of the contacts between geological units, also called horizons, have been implemented. Also taking into account their evolution along the different boreholes selected by the user to generate the ground model and the 2D geological profile.

This procedure requires as input data: the geolocation of the boreholes (or Ground Information Points - GIPS) within the cross-section, the elevation of each borehole (considering a global reference system), the vertical distribution of the geological units within the borehole and the position of the contacts (levels) between the different geological units of the borehole. These levels are provided in a local reference system in which the top of each borehole will always be the 0m level and the levels of each contact will increase with depth successively taking into account the unit thickness.

Considering the initial information and following the PLAXIS guidelines for defining boreholes and generating cross-sections, a general template of geological units is built considering the unit distribution of all boreholes selected to generate the cross-section. In other words, the general template is obtained analyzing the evolution of the unit contacts along the sequence of boreholes selected for the cross-section.

Once the general template is obtained, it will be applied to each borehole merging both the original unit distribution of each borehole and the unit distribution of the template. Knowing that the unit distribution of the template will always include a number of units greater than or equal to the original unit distribution of each borehole (since the template has been built considering the units that compose all the boreholes of the cross-section), if there is a unit in the general template that does not match any original unit of the borehole, this unit is going to be considered as a zero-thickness unit in the borehole.

This information is saved in a such structure that may be easily transmitted to PLAXIS through its API using different preestablished commands and instruc- tions. As a result, a 2D cross-section is built as a starting point to define a Finite Element model. Addi- tionally, as it was mentioned at the beginning of this section, an output result is obtained from this proce- dure to be visualized within DAARWIN platform. This result file contains the layout of the cross-section in different polygons and their relationship into geological units. These results are stored in a such way that may be easily transferred and displayed within DAARWIN web platform.

Considering all above, the data flow from the bore- hole initial information to the generation of the 2D cross-section proposal is depicted in Fig. 1.

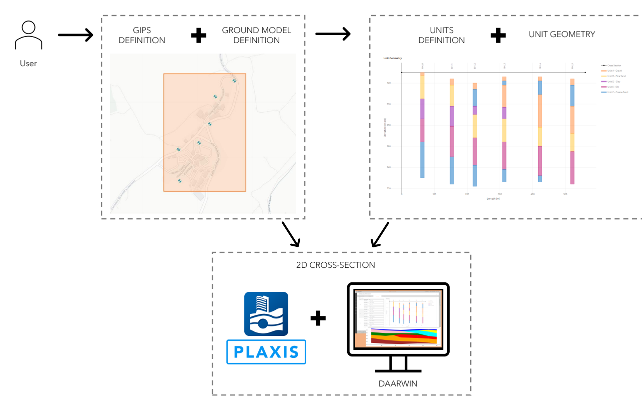

Figure 1. 2D Cross-section workflow within DAARWIN.

3. Results and Discussions

The methodology proposed in this article to per- form a complete ground model has been successfully reproduced in real examples of geotechnical profiles. A representative case has been selected to show the general workflow of the ground model within DAARWIN web platform from inputting Ground Information Points (GIPs) to the 2D cross-section generator using PLAXIS as output. An illustrative description of the ground model workflow steps is shown as follows:

- Uploading GIPs to DAARWIN system from different sources: manually by the user, in a digital standardized format such as AGS, or by digitizing scanned legacy borehole log records (Fig. 2).

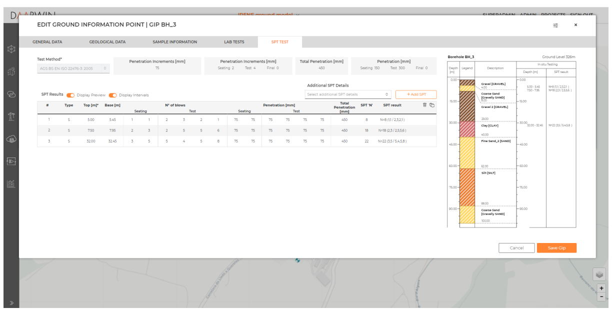

Figure 2. Uploading GIPs to DAARWIN

- Selection of the GIPs to be considered for the ground model as well as area where the ground model will be located. This information is stored in DAARWIN's relational database to be available during the ground model workflow (Fig. 3).

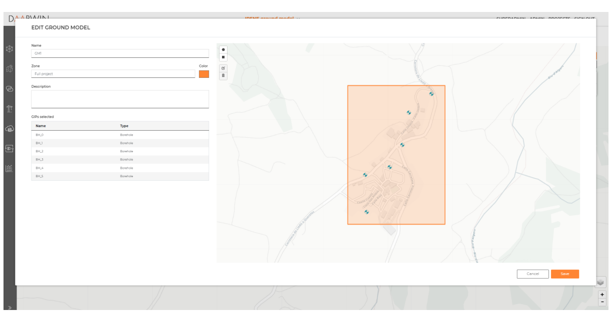

Figure 3. GIPS and Ground Model definition within DAARWIN.

- Generally, both borehole location and vertical layout of geological layers and their description are available for each GIP and queried to the database and provided to the user at this time. Then, the user starts the definition of the geotechnical units by interpreting the previously mentioned information, as well as geometric relationships between nearby GIPs. At this step, the user will associate and even group layers into units based on geometry aspects as well as results of in-situ and laboratory tests (Fig. 4). This can be done in DAARWIN's GIP View screen (Fig. 5).

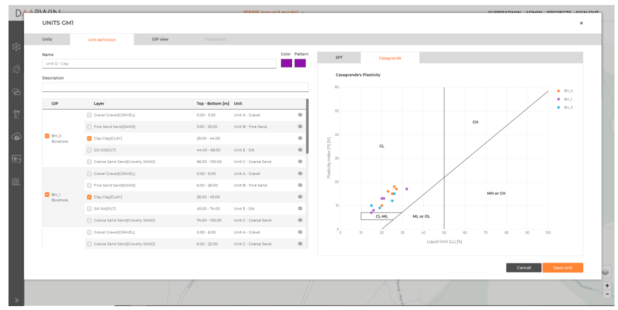

Figure 4. Casagrande's Plasticity plot for Clay unit

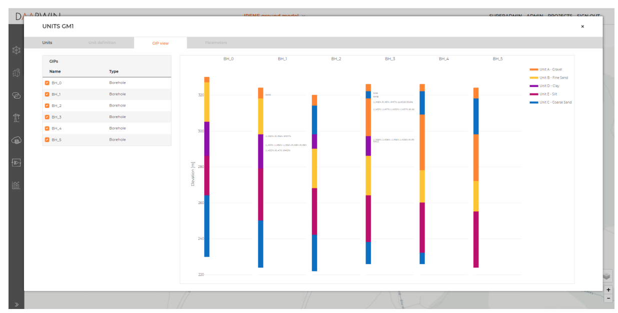

Figure 5. Units definition within DAARWIN's GIP View.

- In the next step, the user draws the cross-section on the map and a view including the GIPs at the corresponding projected distance (Fig. 6), and their units is outlined (Fig. 7).

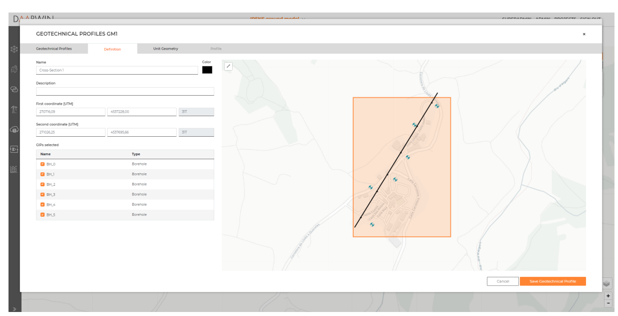

Figure 6. Cross-section trace within the ground model area in DAARWIN.

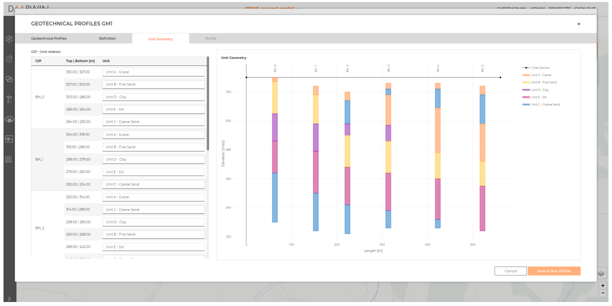

Figure 7. Unit geometry view within DAARWIN.

- The final step consists in transferring appropriately all the data to PLAXIS software to generate the cross-section. It is important to mention that all borehole information is processed into a data structure to be sent through the PLAXIS API according to the procedure described in the previous section. Python programming language has been used for this development as well as PLAXIS 2D version 2023.2 (Brinkgreve et al. 2016).
  As a result, the geotechnical profile proposed by the 2D cross-section generator in this case of study is the one depicted in Fig. 8.

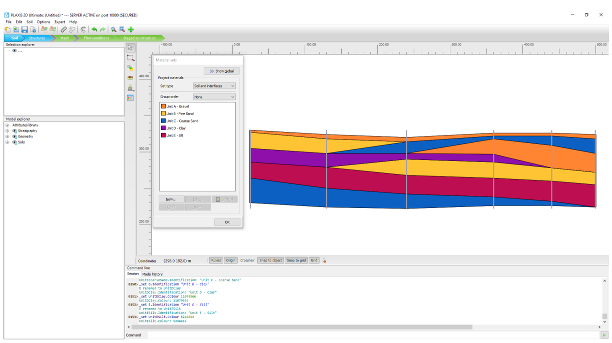

Figure 8. 2D cross-section proposed represented through PLAXIS.

4. Conclusions and Future work

Ground characterization plays an important role in any geotechnical design since it allows the geotechnical engineer to evaluate and interpret the spatial distribution of the materials in the subsurface as well as relationships between their physical and mechanical properties. This geological and geomechanical interpretation becomes the basis of a ground model and for this reason it is important to provide a reliable tool capable of performing ground models with greater ease and efficiency. The ground model workflow presented in this article constitutes a step forward in this area. In this case, when implemented within a web application such as DAARWIN, it is possible to centralize all the processes and functionalities required to generate a ground model such as storage, management, visualization, and analysis of ground information.

Regarding future work, some new developments are currently on-going to fine-tune the user flow and improve performance such as: implementing tools within DAARWIN to visualize the generated cross-sections, considering geological discontinuities such as faults, develop and implement a cross-section generator within DAARWIN, add geological criteria in terms of structural events such as erosion, compression/extension processes, intrusions, etc. to the ground model and to extend the ground model to three-dimensional geometry.

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