The use of 3D digital implicit geological models on slope stability evaluation

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ABSTRACT: This study highlights the importance of efficient and agile methods in geological-geotechnical evaluations for open pit mining. The use of 3D geological modeling technologies allows for a better understanding of lithological contacts and strength parameters, enabling the assessment of rock mass geometry and slope stability analyses. Implicit modeling software facilitates the creation of detailed geological-geotechnical models, which can be updated with new data. These models provide cross-sections for slope analysis and can simulate future mining progress and water level fluctuations. By utilizing these tools, the quality of evaluations improves, and areas requiring additional information are identified. The paper presents the results of an implicit geological-geotechnical model for an open pit mine and showcases a slope stability analysis conducted on a geological-geotechnical cross-section. Overall, these techniques enhance understanding, improve analyses, and contribute to more reliable open pit mine design.

Keywords: Slope Stability, Stability Analysis, Softwares, Geotechnics, Implicit Model.

1 INTRODUCTION

The advancement of technologies has been generous with mining processes and especially their projects. In the field of geotechnics, softwares simulates future situations that bring greater security to operations with much greater agility than those carried out in the past.

Using data inputs from reserves, mining pits in their operational or final geometries and geotechnical parameters of the materials involved in the activity, it is possible to simulate the safety and stability factors of structures. A simulation can also be carried out and, stacks with geometries in execution or final pits, it is possible to monitor the stability of their constructions throughout the evolution, until the end of the project is reached. Such simulations can be carried out in other civil works such as dams, buildings and bridges, for example, but this is not the focus of the current article.

2 MATERIALS AND METHODS

In order to obtain the safety factor and stability results of a mining open pit, we need some data that would make it easier to obtain the results and to support a better connection between the model and the reality.

It is therefore necessary to create have a block model with well-defined lithologies, refined the drilling with information from drilling, mapping, detailing in the descriptions and as much information as possible for this block model, which makes the analyzes more accurate and reliable. Still on the block model, the smaller the edges of these blocks, the greater detail we will have in the digital model, this makes the lithological contacts be delimited as close to reality, thus bringing more confidence to the analyses.

A well-detailed geomechanical model is also an important factor for the study, thus showing the degrees of weathering of the rocks, rock transitions within the same lithology, presence of fractured zones and other more susceptible to the influence of water and weathering and the type of material that develops.

Sampling of rock and soil must be carried out after a previous knowledge of the rock mass and, in this way, the sampling sites are better located, and the collection points are chosen, later bringing a range of values and parameters for each lithological type. By doing this, a model will be supplied with information that will serve as input for the software that calculates the stability analysis of future geometries.

After obtaining these parameters from the physical part of the rock mass, the study can proceed to the analysis part. Softwares such as DataMine Studio, Leapfrog Seequent, or Deswik Cad can be used as generators of this 3D digital model, grouping the solids of the digital block model and the geometries to be analyzed. Then the sections are exported to a slope stability analysis software, such as Rocscience slide2, GeoStudio or any other one. These 3D digital model softwares have functions for automatically exporting data to the slope stability analysis softwares, or the process can be carried out entirely manually, exporting an image and determining the section areas composed of each lithological type.

In the current study, a section taken from a section image in the Leapfrog software is demonstrated. Leapfrog uses implicit modeling to generate its models and, therefore, with drilling holes, a geological/geomechanical model is established, generating rock solids according to their evolution in geological time.

To make it as didactic as possible, a completely manual process is performed to remove Leapfrog data to the slope stability software, in the present case, Slide 2D. First, in Leapfrog, the geological and geomechanical model data are loaded into the software, from the block models, thus generating a 3D solid in the software with the rock mass. The bocce model data makes the process much easier, but this data can be generated with existing drilling holes with data from Excel or any commercial sheets software.

The topographic surfaces, both current or future projects, are then uploaded so that, in the interface with the geological/geomechanical model, the geological sections with the surface limits are extracted and can be exported to Slide 2D.

One must then choose the location of the sections to be analyzed, for example the sections exemplified in Figure 1, which represent the weakest zones of the rock on the current slopes. Therefore, the places where the sections will be constructed must be chosen. The factors for selecting these sections' position can be:

- Fractured zones or with families of persistent discontinuities;
- Zones with a high degree of weathering;
- Very steep slope face regions;
- Very high interramp or global angle regions;
- Factors that bring some weakness or intrinsic, particularities in each rock mass.

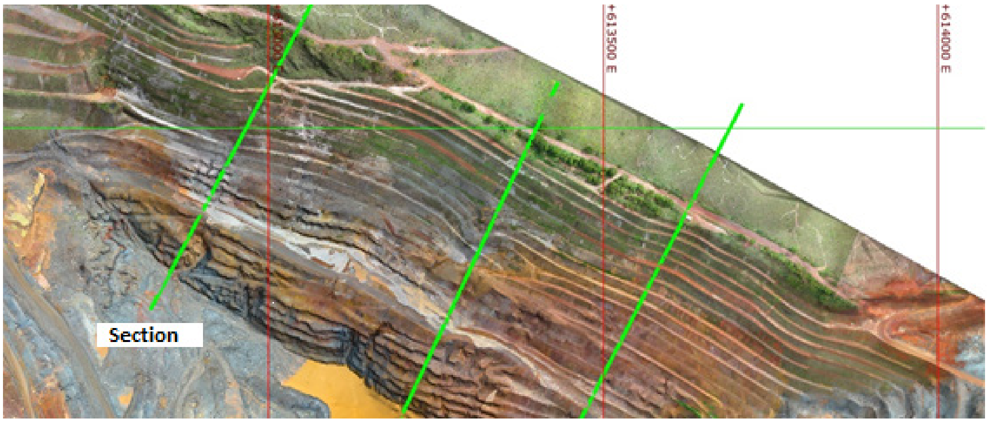

Figure 1. Examples of sections chosen at Leapfrog.

To generate the sections, Leapfrog has a function that allows the user to take a picture of the image that one want to export, therefore, choose the plan view, where you can see it from the top of the surface (looking down) and use the “slice” function of the top to bottom of the chosen section.

After cutting the section, using the keyboard button “L” will give the user the side view of the section. If the user prefers the other side of the section, he can use “shift + L” for a completely lateralized view of the section. A thickness of 1 meter is then established for the slice, making the colors of the lithological types appear only in that section to be calculated. In the geological model, a transparency of 50% is established so that the topographic surface stands out from the geological model, thus having a view of the section for which the FoS (Factor of Safety) is to be calculated (Figure 2).

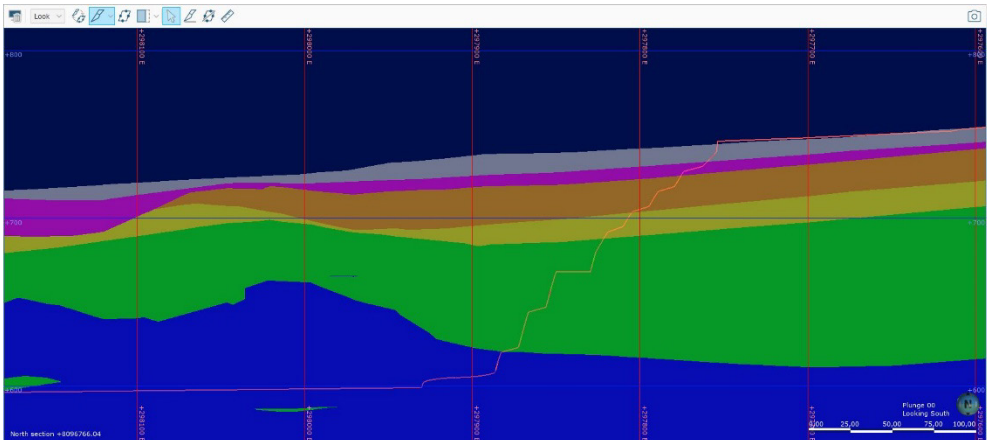

Figure 2. View of the Leapfrog section showing the scale, geological model and topographic surface.

Once the section is established, one can use the closest possible view, as in this way the image is better detailed, always observing the dimension and scale measurements that appear in the scale grid, both in dimension and in lateral distance.

The Leapfrog has georeferenced Y dimension and X distance markings and, therefore, when extracting the section, it will be in scale, so that the calculations could be better defined in the Slide 2D, since the size scales are essential for these size and masses calculations and the slope stability results are reliable. Then, the user can use the “Picture” function to generate an image, that can be exported in .jpeg format, which is the format that the Slide 2D reads. The action is repeated for all the sections to be evaluated.

Once the image is exported, the Slide 2D can be run. The configurations and geotechnical parameters of the materials to be calculated are defined, and the software will be configured so that the evaluations of the sections taken from the Leapfrog software are performed.

The image of the cross section to be analyzed is then loaded onto the “Add Image” icon. When adding the image, one can left click on the image and select “Scale Image”. A point is then selected in the lower left corner, the X & Y values are established, and then a point on the extreme diagonal of the image selected, determining the X & Y of the image, and then the image is referenced and scaled.

An external boundary must be generated for the section that one wishes to calculate the FoS in “Add External Boundary”, using the topographic surface chosen as a reference and a polygon is generated. Within this polygon, the contacts between lithological materials differentiated by the colors of the model generated in Leapfrog are traced using the tool “Define Materials” and thus, all the lithological types of the section are delimited (Figure 3).

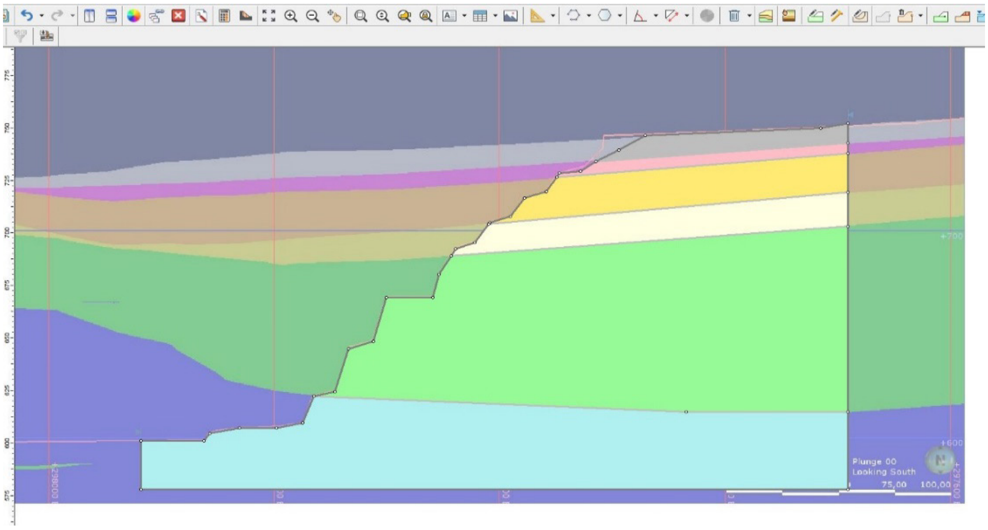

Figure 3. Example of Slide2 view with the Leapfrog section picture and the generated geometry in the front.

Once the lithological bodies are determined, the “Assign Properties” tool is used to determine each material with its different geotechnical parameters in cross-section. After the determination of parameters for each lithological type is finished, the activity related to the section and the rock mass is finalized.

Finally, use the “compute” function, wait for the software to calculate, and use the “Interpret” function for the result, and obtain the section with the safety factor of your chosen surface. Figure 2 below shows the result of a slope stability analysis (Figure 4).

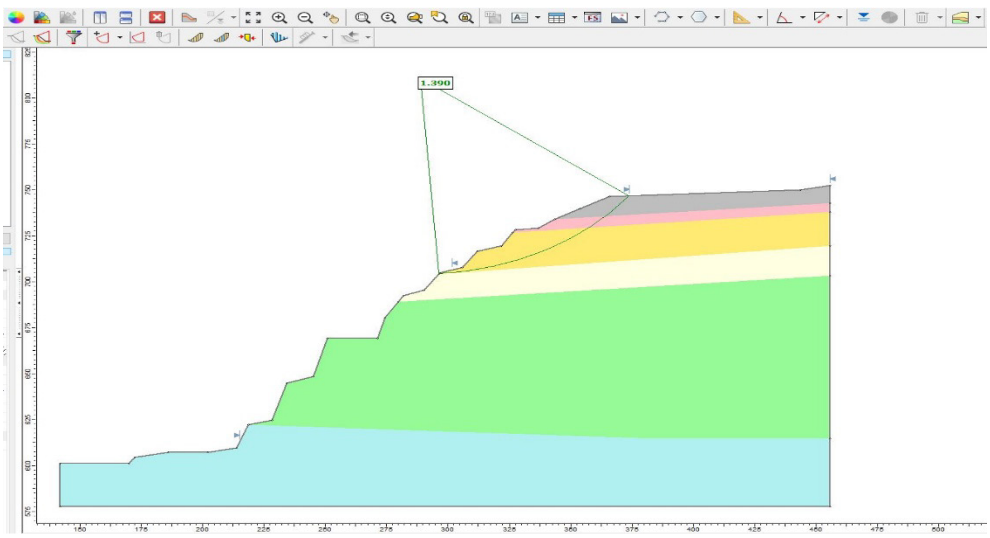

Figure 4. Example of FoS calculated.

3 CONCLUSION

The increasing offer of 3D modelling softwares has allowed a better tool for the 3D geological and geomechanical modelling of open pit mining sites. These tools support a better representation and definition of geological and geomechanical units in 3D and so, a better understand of the geomechanical materials involved in slope stability.

Geologists and geotechnical engineer have a reliable methodology using 3D modelling softwares as a source of information for the stability calculations of a geological/geomechanical model generated with implicit modeling, and this model can be replicated for various types of pit structures, piles, dams and other structures that has civil works interface with rocks and soils and easily updated with new gathered information.

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