Stress-Strain Behavior of a Bauxite Tailings Dam Based on Field Monitoring Data

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Abstract

In Brazil, the need for automatic alert system activation of tailings dams based on deformation and displacement criteria raised the importance of stress-strain modeling as a fundamental approach. Understanding the stress-strain behavior of the materials that composes a geotechnical structure is relevant for a fair estimate of its displacements, complementing the evaluation of their operational and safety aspects. However, the components materials of a geotechnical structure present natural variability in their properties inherent to their state. This study proposes a phenomenological approach to simulate the deformability behavior. Additionally, this paper presents the calibration of such parameters based on laboratory and field tests and monitoring data, aiming to reduce the uncertainties and better characterize their behavior. A numerical stress-strain model developed considered the finite element method and classical constitutive stress-strain models, such as the Linear Elastic and the Elastic Perfectly-Plastic Mohr-Coulomb model. The simulations considered the constructive sequence of a bauxite tailings dam and its history of tensions and displacements based on project aspects, loadings, and the construction timeline. Also, to characterize the constitutive models, a statistical evaluation of each material's strength and deformability parameters was considered from laboratory and field tests – mainly SPT and CPTu. Additionally, the back-analysis based on the field monitoring data registered by the inclinometers installed in the structure for the past five years supported the refinement of the input parameters. As a result, after calibrating the deformability parameters, the numerical model could satisfactorily replicate the displacement registered by the field monitoring instruments. The model is the primary tool to define the reference displacements expected for the structure's lifecycle.

Keywords: Stress and strain, Bauxite tailings dam, Numerical back-analysis.

1. Introduction

Tailings structures become exposed to constant changes in loads and, consequently, in their stress state. Thus, the knowledge of the stress-strain behavior becomes an important tool, identifying the influence of some physical phenomena on their safety and stability conditions, in addition to allowing a better understanding of the expected displacements for different operating conditions of the structure.

The numerical modeling results could be compared with the dam's monitoring data and knowledge database. The main variables are absolute displacement and acceleration of change and help track anomalies or not expected behavior regarding the foundation, embankment, or instrumentation deviation.

The stress-strain behavior of the tailings dams is important not only during construction or uplifts but also because the stress-strain state of the core at the end of construction is the starting point

for the subsequent analyses when subjected to different loadings and deformations during impoundment and operation [1].

The geological setting of the studied dam is located in Paragominas, representing one of the most important and expressive groupings of bauxite deposits worldwide. This province contents in the southern portion of the Itapecuru Group (K12it) from the Cretaceous, composed of archosean sandstones with crossbedding, marked by coarse to conglomeratic granulometry. In contrast, such sandstones are interspersed with pelitic levels, linked to an evolutionary moment of lower deposition energy. This group and its lithologies come from coastal, lagoon, fluvial, and tidal sedimentary environments, showing the eustatic variations that occurred over geological time [2].

In the northern portion of the bauxite deposits, the sandstones from upper-Cretaceous Ipixuna Formation (K2ip) stand out, marked by sandstones wrinkled with kaolinitic cementation and primary structures represented by crossed stratifications, with un-iron claystone levels linked to fluvial-lacustrine and estuarine environments. These layers are lithostratigraphic units belonging to the Grajaú Basin. This lithostratigraphy and chronostratigraphic context are based on the Valley System foundation rocks [2].

The tailings dam disposal facility, presented in Figure 1, has 1,680 m of crest length and has been five times heightened. The dam is an earth embankment, and all stages of uplift have been well documented. The instruments used in this study were inclinometer and topographic marks with regular reading since 2017.

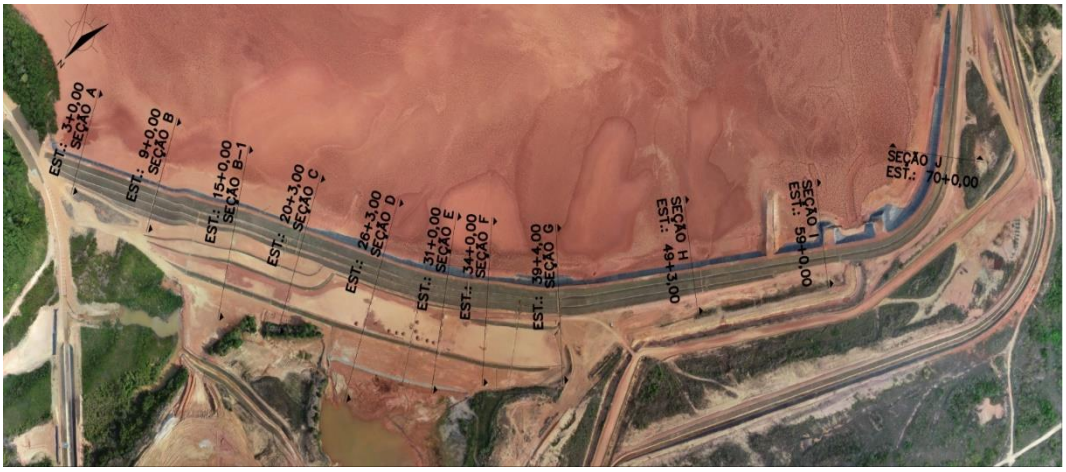

Figure 1. Sections B1 dam, Hydro Paragominas.

Numerical analyses have been used to analyze the behavior of the dam body. The material parameters were obtained by conducting field sampling and laboratory tests at different dam construction and operation stages.

2. Material and Methods

Given the need to understand the deformations experienced during construction and expected for the operation of a bauxite tailings dam, a numerical model of stress, strain, and pore water pressure was developed in three steps: consolidation of the input data for the model, construction of the numerical model and calibration parameters based on monitoring data from geotechnical instrumentation installed in the field.

must be robust enough to bring more assertiveness to the back-analysis and, consequently, the calibration.

It is worthy to note that the present study is limited to the input and database of the instruments adopted in calibrating the numerical model. Nevertheless, the model can be understood as a primary tool to define the reference displacements expected for the structure's lifecycle, specifically when involving non-tested materials. The authors suggest this methodology be assessed with site instrumentation readings for full laboratory-tested materials, leading to more accurate constitutive models.

5. References

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