Presidential Address: Managing geotechnical uncertainty and risk in mining

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Synopsis

The science of soil mechanics is 100 years old, and rock mechanics is about 80 years old. While methods of analysis and design have been developed and have evolved over time, these are relatively young sciences. The rapid increases in computing power and new technologies have enabled more sophisticated modelling and monitoring. However, there are still many aspects of soil and rock mechanics that are not well understood. Geotechnical failures, which have major consequences, still occur. These consequences may include environmental damage, major production holdups and associated loss of revenue, damage to infrastructure, and loss of life.

High-consequence events, which are rare, are more difficult to anticipate and to design for, because by their nature they involve extraordinary circumstances or conditions, often geological in nature. The risks are usually mitigated by conservative designs and monitoring. Detailed geotechnical investigations help us to understand the natural variability of soil and rock masses and identify unusual or unexpected conditions. Investigating and researching major geotechnical failures is essential to enable these unusual circumstances to be anticipated.

In the past, severe unanticipated events may have been treated as natural events or 'acts of God'. However, society now has much greater expectations and it is essential to have policies and procedures in place that enable appropriate management of these rare, high-consequence risks. A good example is the Global Industry Standard on Tailings Management (GISTM), which was introduced after the catastrophic dam collapse at Vale's Corrego de Feijao mine in Brumadinho, Brazil.

The address will explain the concepts of uncertainty and variability, and how they should be taken into account in geotechnical design. The challenges facing geotechnical engineers, mine owners, and managers will be discussed. referencing a number of real case studies.

Keywords

uncertainty, variability, risk, consequences, environmental, social, production, revenue, damage, geotechnical, soil mechanics, rock mechanics, design, mine layouts, GISTM, tailings dam, pillar, failure, mechanism, model, seismic, rockburst.

Introduction

Modern soil mechanics is generally considered to have begun in 1925, when Karl Terzaghi published his book *Erdbaumechanik auf bodenphysikalischer Grundlage* (Earthwork Mechanics based on the Physics of Soils). These theories were applied to rocks more than 20 years later and the science of rock mechanics became established. Methods of analysis and design have been introduced and applied, and have evolved over time. More recently, the rapid growth in computing power has resulted in more sophisticated analyses, and together with improved monitoring techniques, our understanding of geomechanics has grown considerably.

Despite this, geotechnical failures with major consequences still do occur. This is partly due to failure to transfer and apply the knowledge that has been gained, but also there are aspects of geomechanics that are not well understood.

Uncertainty and variability

Geotechnical engineering is subject to a lot of uncertainty and variability which need to be considered in the design process and in the management of geotechnical risks. This subject is discussed by several authors (Stacey, 2003; Christian, 2004; Stacey, Terbrugge, and Wesseloo, 2006; Hadjigeorgiou and Harrison, 2012; Joughin, 2017; Hadjigeorgiou, 2019; Wesseloo and Joughin, 2020; Joughin *et al.*, 2020). These terms can be defined as follows.

- Variability is a property of nature. Rock mass and soil properties, as well as loading conditions, span a large range of values, which can vary in space and time. Variability can be described with statistics and the probabilities related to variability can be interpreted in terms of frequency of occurrence (Figure 1).