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Forensic analysis of the instability of a large-scale slope in a coal mining operation

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ABSTRACT

In this study we present the results of the forensic analysis of the slide in the large southern slope of an open-pit coal mine located in northeast Spain. The slopes have a total height from 100 m to 350 m. The mine's benches are 10 m in height and the berms have a width of 5–6 m. Along the entire length of the southern slope there is a fault of significant size which is close to the Romera seam. This seam is mined via underground mining operations. The entire Southern slope presents a series of significant strains and even some examples of subsidence on its head. It is believed, in principle, that these are a result of interaction between the Romera seam operations and the above mentioned fault. The northern, eastern, and western slopes do not, however, show any signs of failure. In order to analyse the above hypothesis we have created and calculated, using numerical methods, a two-dimensional model that represents a cut parallel to the path of the analysed slope. This modelling technique has been used to analyse the degree of alteration to which the rock mass formed by the slope has suffered. An analysis of results during the different phases of mining operations indicates that underground operations carried out in the small seams to the left of the fault only cause minor alterations to occur. Something similar occurs during the first phase of operations performed using sub-level caving of the Romera seam. Nevertheless, the second phase of operations in that seam results in significant changes to the slope. The fault is affected, and blocks are displaced by distances of up to 13 m. This phenomenon also causes considerable surface-level subsidence.

The interest of this study resides in combining the experimental results obtained from field tests and strains registered in the galleries using a numerical model that allows us to evaluate the state of stress and strain in a highly detailed manner for the area under study.

1. Introduction

The coal mine analysed is situated in northeast Spain (Fig. 1). It is a large-scale open-pit consisting of alternating lutites, sandstone, and seams of coal, distributed evenly over the four slopes that make up the open pit. The slopes are very large, with a total height from 100 m to 350 m. The mine's benches are 10 m in height and the berms have a width of 5–6 m.

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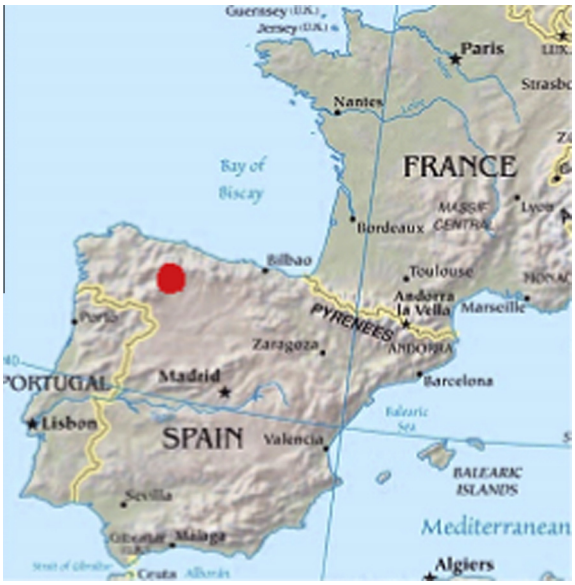

Fig. 1. Location.

Although coal is extracted by open-pit mining operations, underground operations are also performed in the southern slope to mine some of the existing seams of coal.

The coal deposit consists of very thick, highly irregular vertical and sub-vertical seams [1]. Of all of these, the Colmena formation is that of greatest financial interest, as it is this formation that provides all of the coal production for the current mining centres. Operations currently focus on the western edge of the coalfield. The Colmena and Romera seams are the thickest seams in the Colla–Maragata coalfield.

The Colmena seam (Santa Lucia group) runs for 1600 m in a primarily north–south direction, with varying gradients for its sides, with values close to 30°. Its thickness varies from 7 to 40 m, and within the seam there are bands and wedges of varying thicknesses, shaped like lenses, of varying hardness and composition, ranging from soft slate to sandstone.

The area where mining operations are performed on the Romera Seam runs some 1680 m in a majorly north–south direction with its side gradients ranging from 60° to 80°. Its thickness varies from 2 to 25 m, with a thickness of 14 m being the most usual.

From a geological standpoint the Colla–Maragata coalfield is located in the western branch of the Somiedo–Correcillas unit. It is located in the Cantabrian zone [2], in the outermost area of the Hercynianorogeny in the north of the Iberian Peninsula.

The coalfield is a synclinorium with a North–South axis (extending in this direction some 15 km) and a width (East–West direction) of some 5 km.

2. Slope description

In order to describe the rocky materials that make up the slopes of the mine under study, we performed an exhaustive ground survey where the following tasks were performed:

- Analysis of the different types of materials present in each area of the mine.
- Study of the degradation of slopes as a result of instability problems.

Analysis of the different types of materials was performed exhaustively along the different benches of the mine. We thus determined the characteristics and distribution of the lithologies that make up the mine's slopes. Each of the identified types of materials is found in very specific areas in the mine. Most of the open pit consists of lutites, sandstones and coal seams. Their distribution is not uniform; for example, in the upper part of the southern slope there are hardly any traces of coal and the presence of sandstones predominates over lutites. There are significant seams of coal interspersed between lutites, and to a lesser extent, sandstones, in the centre and lower section of the southern slope (Fig. 2).

In addition to these lithologies, it is worth noting the presence of a limestone rock mass in the eastern slope, which limits the operations on that face (Fig. 3).