International Journal of Mining Science and Technology 26 (2016) 65–70

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Effect of discontinuities characteristics on coal mine stability and sustainability: A rock fall prediction approach

Oraee Kazem [a], Oraee Nikzad [b,*], Goodarzi Arash [c], Khajehpour Parham [d]

[a] University of Stirling, Stirling, United Kingdom
[b] Centre For Environmental Policy, Imperial College, London, United Kingdom
[c] Ministry of Labor, Tehran, Iran
[d] Iran Minerals Production and Supply Company, Tehran, Iran

ARTICLE INFO

Article history:
Received 27 July 2015
Received in revised form 11 October 2015
Accepted 30 October 2015
Available online 23 December 2015

Keywords:
Discontinuities
Rock fall
Coal mine
Prediction
UNWEDGE
Sustainability

ABSTRACT

Rock fall related accidents continue to occur in coal mines, although artificial support mechanisms have been used extensively. Roof stability is primarily determined in many underground mines by a limited number of methods that often resort to subjective criteria. It is argued in this paper that stability conditions of mine roof strata, as a key factor in sustainability in coal mines, must be determined by a survey which proactively investigates fundamental aspects of said mine. Failure of rock around the opening happens as a result of both high rock stress conditions and the presence of structural discontinuities. The properties of such discontinuities affect the engineering behavior of rock masses causing wedges or blocks to fall from the roof or sliding out of the walls. A practical rule-based approach to assess the risk of a roof fall is proposed in the paper. The method is based on the analysis of structural data and the geometry and stability of wedges in underground coal mines. In this regard, an accident causing a huge collapse in a coal mine leading to 4 fatalities is illustrated by way of a case study. Horizontal and vertical profiles are prepared by geophysical methods to define the falling zone and its boundaries. The collapse is then modeled by the use of sophisticated computer programs in order to identify the causes of the accident.

1. Introduction

Rock fall related accidents continue to occur in coal mines, although artificial support mechanisms have been used extensively [1]. Roof stability is primarily determined in many underground mines by a limited number of methods that often resort to subjective criteria. The stability conditions of mine roof strata is a key factor in ground control in coal mines and must be determined by a survey which proactively investigates fundamental aspects of said mine.

Failure of rock around the opening happens as a result of both high rock stress conditions and the presence of structural discontinuities. The properties of such discontinuities affect the engineering behavior of rock masses causing wedges or blocks to fall from the roof or sliding out of the walls [2].

The major proportion of developing countries' coal is excavated through artisanal methods in small-scale mines. Roof stability is not studied thoroughly in many small underground coal mines; for example, structural instabilities tend to be ignored whilst properties of such discontinuities affect the engineering behavior of rock masses.

The determining the active structural discontinuities that led to the fall of wedges or blocks from the roof, or sliding out of the walls of the mine opening, is a difficult technical task that is related to mapping and modeling discontinuities.

There are many lessons to be learned from almost every roof fall accident and but generally the factors contributing to the accident are not clear. Much of the evidence is almost fully destroyed in a huge collapse such as the collapse of a hanging wall.

2. Discontinuities in coal strata

A discontinuity is defined as a separation in an intact rock where two of its dimensions are several orders greater than the third dimension. Geometric and mechanical characterizations of rock discontinuities are important in modeling process.

Coal strata contain discontinuities of various types. The discontinuities of coal and its surrounding rock are divided into two types: (1) discontinuities occurring post-peat accumulation (faults,

* Corresponding author.
E-mail address: n.oraee10@imperial.ac.uk (N. Oraee).

http://dx.doi.org/10.1016/j.ijmst.2015.11.012
2095-2686/

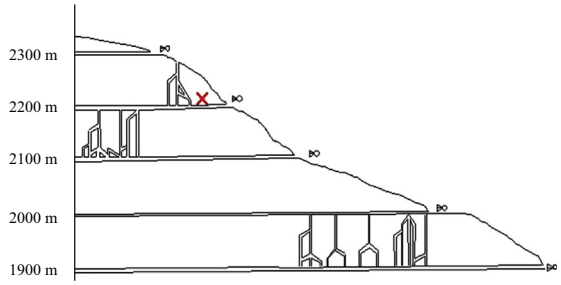

Fig. 1. Sketch of Eshkeli Coal Mine. (*Note:* × refers to accident place.)

joints, cleats, etc.) and (2) discontinuities occurring contemporaneous with peat accumulation (bedding planes, slickensides, etc.). In fact, they are rarely homogenous and isotropic in most continuum mechanics theories. Since discontinuities are the weak component, they control the strength of the rock coal seam [3].

Coal strata include generally, in descending order to strength (UCS), limestone (40–220 MPa), sandstone (14–145 MPa), siltstone (14–130 MPa), and shale (<7–110 MPa). Mudstone or clay stone are similar to shale without the laminations. This order of strength is right only when there are no discontinuous features such as bedding separations or fractures in the rock strata.

3. UNWEDGE software

A numerical modeling method is required which can model the presence of discontinuities as well as the failure mechanism of the coal material [4]. UNWEDGE is a computer software program that calculates the possible wedges that can form around the excavation by the intersection of the three discontinuity planes of the excavation. Wedge geometry (orientation) and the strength characteristics of discontinuity planes (discontinuities shear strength) that create the wedge and stresses within the coal bed play a role in wedge stability.

The orientations of 3 distinct discontinuities may be defined by the geophysics' profiles. The wedges are considered tetrahedral and the 3 discontinuities planes make up 3 sides of a tetrahedron and fourth side is formed by the excavation boundary.

The stope axis orientation is defined by the trend/plunge of the stope axis. In general, for any excavation orientation, the opening section is always a cross-section perpendicular to the trend/plunge of the excavation axis.

The shear strength of the discontinuities which separate the blocks controls stability of the system of individual rock blocks. Shear strength of the discontinuities are analyzed by Mohr–Coulomb method ($\tau = c + \sigma_n \tan\varphi$) in the project. Here, τ is the shear strength of the discontinuity; c the cohesion; σ_n the normal stress; and φ the friction angle of the discontinuity plane. Shear strength is computed based on the normal stress acting on each discontinuity plane. The normal stress is computed based on the active and passive normal forces computed on the discontinuity planes.

The influence of water pressure on the stability of a wedge may be important in some cases but since underground stopes are usually free-draining so the water pressure is assumed to be zero.

4. Roof fall accident in Eshkeli Coal Mine

Eshkeli Coal Mine is located in Iran (Fig. 1). The geological formation of the mine belongs to the middle Jurassic period. The

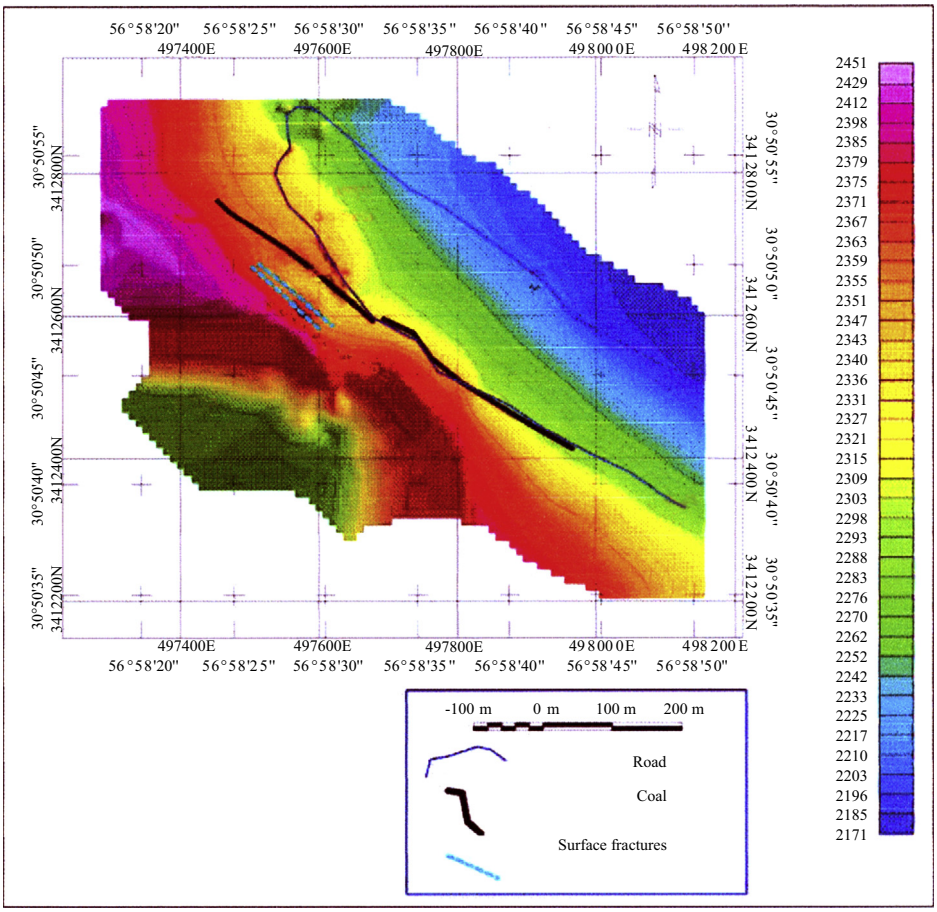

Fig. 2. Topography map of the mine region.