International Journal of Coal Geology 188 (2018) 25–36

Contents lists available at ScienceDirect

International Journal of Coal Geology

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

A physical and numerical investigation of sudden massive roof collapse during longwall coal retreat mining

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ARTICLE INFO

Keywords:
Massive roof collapse
Geotechnical precursor
Longwall coal mining
Physical modeling
Numerical modeling

ABSTRACT

One of the most challenging safety problems in underground longwall coal mining is massive roof collapse in mined-out area during retreat mining. Understanding the mechanisms and geotechnical precursors of massive roof collapse is of great importance for risk assessment and ground control. In this study, a large-scale physical model was created based on a real case to simulate massive roof collapse during longwall coal retreating mining. A good agreement was achieved between field observation and physical result in terms of monitored working resistance, indicating that the physical model is able to capture the realistic response of the rock strata above mined-out area. A numerical model was created based on the model configuration of the physical model. The physical result and the numerical result were in good agreement with each other in terms of many features including roof failure mechanism, abutment pressure distribution and collapsed roof pattern. The physical and numerical result suggested that massive roof collapse is a typical snap-through failure where bedded roof crack through cross joint at midspan. Substantial increase in horizontal stress at the center of the potential failure zone is a reliable geotechnical precursor of massive roof collapse. It is suggested that horizontal stress increasing up to five times pre-mining can be considered as a threshold of the precursor of massive roof collapse.

1. Introduction

In underground longwall coal retreating mining practice, the extraction of a coal seam leaves unsupported roof suspended in the mined-out area. As the extraction proceeds, the unsupported roof gradually collapses into the mined-out area. A timely periodic roof collapse is benefit to the mine safety and ground control. Under some conditions, particularly when the roof is competent, the roof may not collapse, but suspends over a large distance, causing a massive suspended roof. When the massive suspended roof finally collapses, a catastrophic geohazard will often result. A large air rush can be generated by the sudden closure of the mined-out area resulting from massive roof collapse, killing miners, damaging equipment and disrupting ventilation. In addition, massive roof collapse can also trigger mining-induced seismicity.

Understanding the mechanisms and geotechnical precursors of roof collapse is therefore of great importance for risk assessment and ground control. Numerous studies have been carried out to study the mechanisms of roof falls in underground coal mines. Common roof fall mechanisms include cutter roof failure (Gadde and Peng, 2005; Gao and Stead, 2013; Hill, 1986), shear failure (Gao et al., 2014b; Gu and Ozbay, 2014; Sharpe, 1999; Shen et al., 2008), bulking failure and block collapse (Whittles et al., 2007). Besides, understanding the sequence of the geotechnical precursors is an essential aspect of a successful geotechnical monitoring program which allows for timely adjustment of mine design and taking of remedial measures (Szwedzicki, 2001). Shen et al. (2008) performed a field study on the roof fall of a longwall entry and found that the changes associated with roadway roof falls follow a time sequence of initial seismicity, followed by stress changes and then displacement. Gao et al. (2014b) performed a numerical study to simulate roof shear failure using distinct element method and found similar time sequence of geotechnical precursors of roof collapse. All of these studies are focused on small scale roof failure in roadways and intersections. Limited literature on the mechanisms and geotechnical precursors of massive roof collapse in the mined-out area is available. This is partly because geotechnical reports on rock mass failure are often confidential and not widely circulated (Szwedzicki, 2001). In addition, it is difficult to find evidence of common precursors since massive roof collapses happen in the mined-out area and no records are available.

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https://doi.org/10.1016/j.coal.2018.01.013
Received 4 November 2017; Received in revised form 24 January 2018; Accepted 24 January 2018

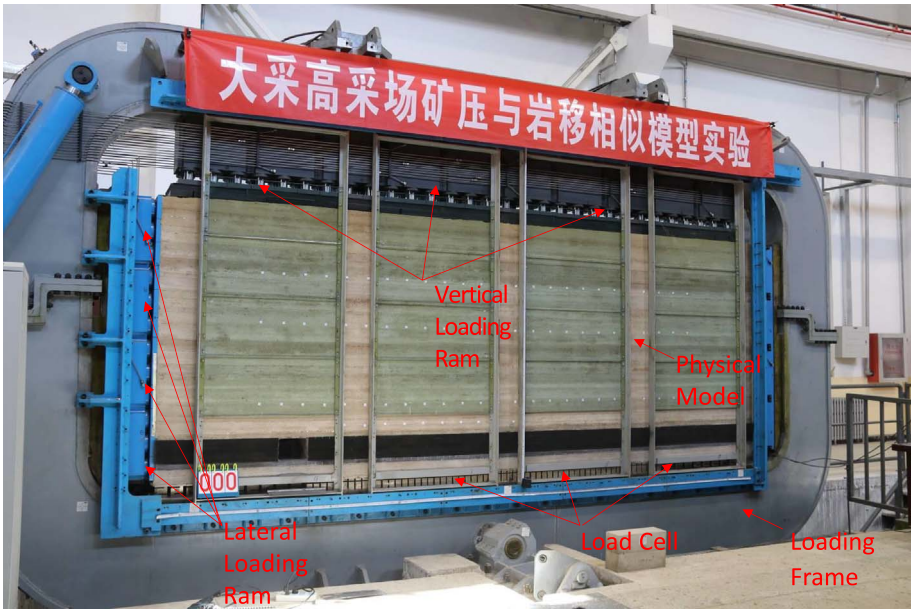

Fig. 1. Physical modeling system for longwall mining.

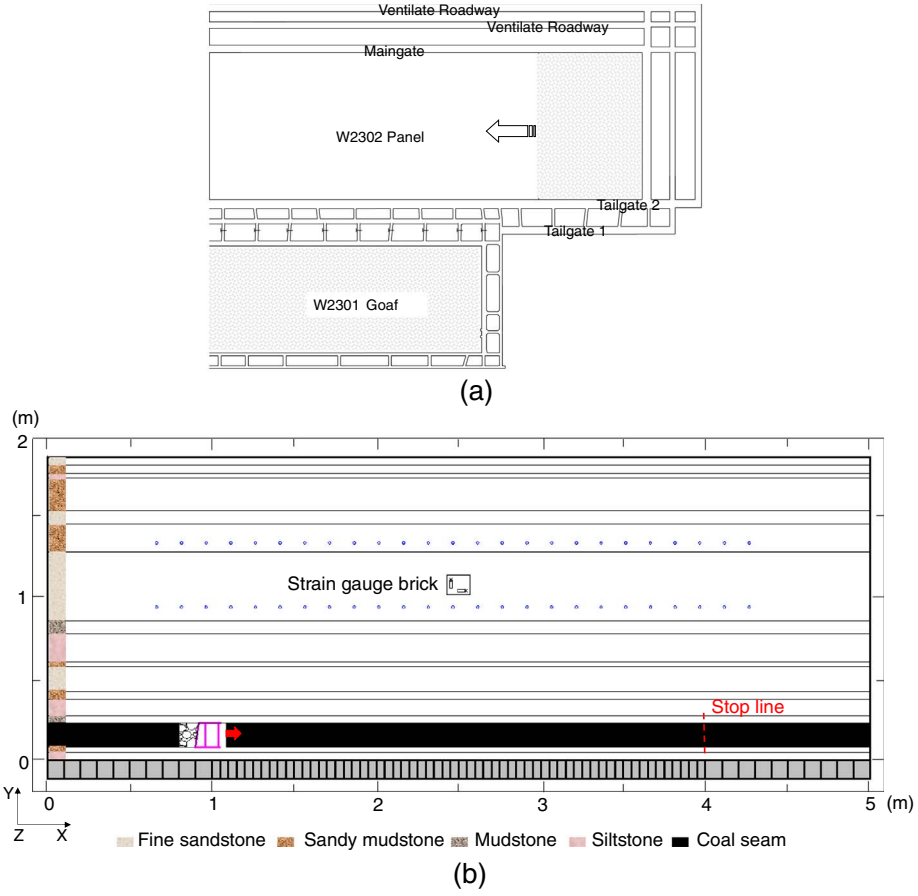

Fig. 2. (a) Layout of study site at the Sihe Coal Mine, (b) Configuration of the physical model simulating sudden collapse of longwall roof.

In this study, a large-scale physical model was created to simulate massive roof collapse during longwall coal retreating mining. A numerical model was then created based on the model configuration of the physical model. The physical result and numerical result were cross checked. Attentions were paid to examining geotechnical precursors of massive roof collapse.

2. Physical modeling of sudden roof collapse

2.1. Physical model configuration

The physical experiments were carried out using a large physical modeling system at the Rock Mechanics Laboratory of the State Key