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Evaluation of pre-jamming indication parameter during blind backfilling technique

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ABSTRACT

Hydraulic blind backfilling is used to reduce subsidence problems above old underground water-logged coal mines. This paper describes experimental research on a fully transparent model of a straight underground mine gallery. An automatic data acquisition system was installed in the model to continuously record the sand and water flowrates along with the inlet pressure of the slurry near the model's inlet. Pressure signature graphs and pressure loss curves with bed advancement under different flow conditions are examined. Pressure signature analyses for various flowrates and sand slurry concentrations are conducted to evaluate a pre-jamming indication parameter, which could be used to indicate the arrival of the final stage of filling.

1. Introduction

Subsidence from old abandoned underground water-logged coal mines has become an everyday concern for many people living in coal producing regions. In earlier days, most coal mines in India worked under shallow cover and were partially extracted using the bord and pillar system of working. Correct records of the plans for many of these mines are not available and also in many occasions are not reliable. As time passes, the strength of the supporting coal pillars left behind in these abandoned mines gradually reduces and the collapse of several adjacent pillars often leads to sudden subsidence in the overlying region. Deterioration of pillars can also occur due to acid mine drainage in an abandoned mine as reported in a case study of an abandoned coal mine near Carbondale, Illinois, USA (RoyChowdhury, Sarkar, Deng, & Datta, 2016). Walker (1993) shows that when the common 'dilute phase' approach is used, an air/backfill mixture typically consisting of less than 5% backfill material is moved through a pipeline at relatively high velocity when compared to fluid. This approach is used for dry mines or where water is scarce.

Some authors have used a probabilistic approach to evaluate mine subsidence (Galve et al., 2009a; 2009b). To avoid problems of ground subsidence, a backfilling technique is used to fill the void space of abandoned mines (Andreyev & Koons, 2010; Aydan & Ito, 2015; Li & Pengyu, 2015; Li, 2013; Wissmann & Peterson, 2013) without dewatering. Aydan and Ito (2015) have presented the effect of the depth and groundwater on the formation of ground subsidence associated with abandoned room and pillar lignite mines under static and dynamic conditions and discussed the effects on the areas aforementioned abandoned lignite mines. Dang, Liu, He, and Liu (2013) have described research involving a feasibility test using phosphogypsum as a backfill aggregate, focusing on the mixture ratio of filling materials and the filling process.

In the majority of earlier mines lying at shallow depth, depillaring with stowing was not practiced due to several constraints and this has led to a high risk of subsidence in the areas lying above those mines. Therefore, the coal mines which utilized the caving method became either fully or partially water logged and have now become unapproachable. Development of suitable methods to stabilize these unapproachable mine voids has, to date, been neglected.

There are a number of differences between backfilling methods in active, approachable mines and those used in the blind backfilling of abandoned, unapproachable mines. The main difference is the lack of access to the abandoned mine voids. The backfilling operation in active mines can be directly observed and the location of filling can be controlled by suitably guiding and releasing the

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backfilling material directly at the void space which is to be filled. However, in abandoned mines, due to a lack of access, all the work must be done from the surface in a remote-controlled fashion (Pal, 2003; Sand, Boldt, & Ruff, 1990). The area to be filled cannot be directly controlled in such a case.

Hydraulic blind backfilling has three variants, namely, air-assisted gravity blind backfilling (Saxena, Parti, Kumar, & Singh, 1984), pumped-slurry injection (Whaite & Allen, 1975) and simple gravity blind backfilling (Pal, Ray, & Barve, 2001). In the hydraulic gravity blind backfilling method, the slurry of backfill material is fed by gravity through a borehole into the water-logged underground mine until the borehole will not accept any further backfill material. This blind backfilling method has been found to be as equally effective as pumped-slurry injection or air-assisted gravity blind backfilling, especially when flowrates are high (Pal, Mukhopadhyay, Panda, & Tripathi, 2010). The quantity that can be injected down a single borehole depends, mainly, on the flow characteristics of backfill material such as slurry flowrate and sand concentration. By using the gravity blind backfilling technique, the occurrence of sudden, pre-mature jamming is a major hurdle in the filling of large areas from a single borehole. To achieve the successful filling of a large area from a single borehole it is essential to make use of a pre-jamming indication parameter.

The aim of this research is to create a pre-jamming indication parameter through a detailed experimental study of the simple gravity blind backfilling method and in-depth analysis of inlet pressure variation during the process of filling.

2. Materials and methods

A fully transparent model has been created and used in a gravity backfilling set-up to critically examine the filling process and analyze inlet pressure variation during the filling-up of the model.

2.1. Transparent model of a straight underground mine gallery

Fully transparent 14 mm thick perspex sheets were used to construct a model of a straight, horizontal mine gallery of 4.9 m × 0.4 m × 0.3 m in size. The geometric scale of the model is 10:1 and it is used in a gravity backfilling set-up, as shown in Fig. 1. The maximum pressure head of the gravity filling process is kept at 1.5 m. One inlet hole is provided to feed sand-water mixture into the model. After depositing sand from the sand-water mixture, the clean water overflows from the model through two outlet holes provided at the two ends.

2.2. Water feeding and metering arrangement

A small capacity centrifugal pump is used to deliver water through a turbine type flow meter into a mixing funnel. The volumetric flowrate of water is varied by means of a manually operated throttle valve. The water flowrate is measured by the flow meter and displayed on an LED display unit located in the control panel.

2.3. Variable-speed sand feeding conveyor and metering arrangements

River sand is sieved, initially, through a 2 mm sieve to remove oversized particles and then through an ASTM No. 140 sieve to remove finer particles which can hamper the proper visualization of the filling process in the transparent model. It is then stored in a bunker. The sand is then transported from the bunker to the mixing funnel using a variable-speed bucket elevator. Sand flowrate is measured by calibrating the sand quantity transported with the rpm of the bucket elevator. To ensure sand-water slurry of any desired concentration, metered amounts of sand and water are fed into the mixing funnel. As the sand-water mixture gravitates down the inlet feeder pipe, it is mixed thoroughly to form a homogeneous slurry.

2.4. Data acquisition system for continuous recording of inlet pressure of the slurry and sand-water flowrates

An automatic data acquisition system is installed in the computer in the control panel and this receives output signals from the pressure sensor, water flowmeter and sand conveyor rpm meter. The data acquisition software calibrates the received signals in terms of respective units of the measured parameters and records them. Values of the measured parameters are recorded every second. The data acquisition software has the capability to display time-variations of the parameters in graphical form in separate windows as well as record the data in an Excel file.

2.5. Experiments on the maximum area of filling from a single inlet pipe effect with varying slurry flowrate and sand concentration

A detailed experimentation on hydraulic gravity blind backfilling in the transparent test model using the complete experimental set-up, as outlined in the previous sections, was carried out using varying flowrates and sand concentrations. During these

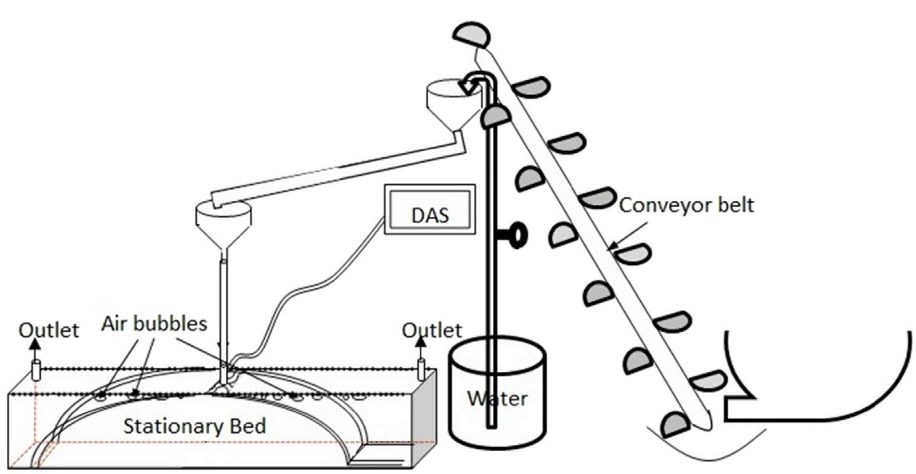

Fig. 1. Schematic diagram of the experimental set-up for gravity blind backfilling.

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