Development of Strata Control Indication Programme During Depillaring

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Abstract: Strata control is a major concern during underground coal mining and needs special attention. Strata controlrelated incidents like fall of roof and sides continued to remain the single largest cause of fatal accidents in underground coal mines. Between two stages of underground coal mining, viz. development and depillaring; major threat comes during depillaring operation when pillars are extracted i.e., removing of thenatural support. Proper addressing of safety issues and its management during depillaring is a great challenge for coal mining industry. This situation during depillaring obviously demands more and more sophisticated and advanced instrumental checking and monitoring of the strata control parameters. Strata control study during depillaring provides data regarding impending abnormal or dangerous conditions/situations in mine workings such as roof fall, development of mining induced stress, bed separation, pillar/stook/rib failure, support performance/failure etc. that action can be taken for safety of theworkers and workings. Proper planning, installation of reliable ground movement sensors with continuous data acquisition system, generation of adequate data, proper and timely analysis of data are the factors for success of strata control study programme during depillaring. This paper describes the need for strata control study especially, during depillaring; the most hazardous operation during underground extraction ofcoal, along with different issues of strata control study like parameters to be measured, sensors to be used, nature of instrumentation and monitoring, etc. including installation of instruments in bord and pillar as well as longwall panels.

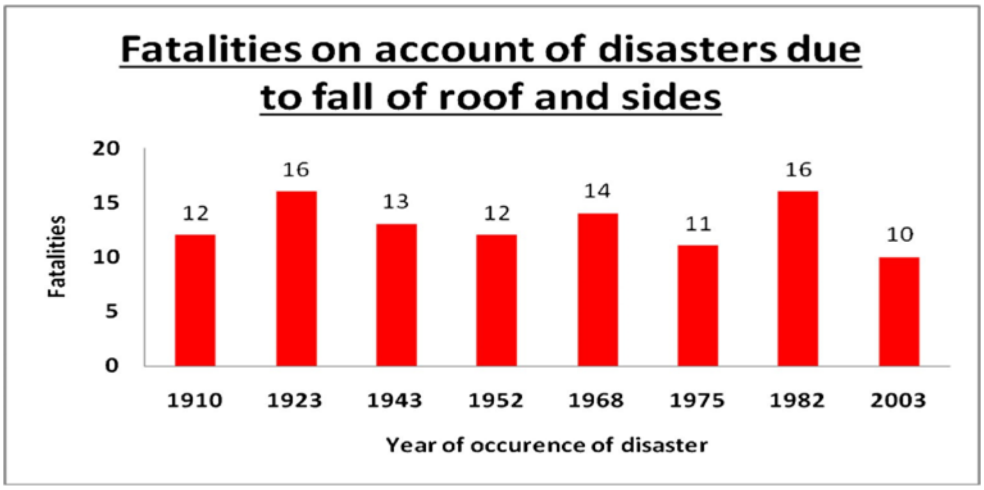
Keywords: Strata, Mining, Dilation, Convergence, Depillaring, Stress and Caving

Introduction

Coal deposits at shallow depth are depleting rapidly because of growing production rate in the opencast mining. In view of this, the issues relating to the success of underground coal mining in India have gained paramount importance. In absolute terms, the success of underground coal mining is subject- ed to optimization of many parameters, such as production, productivity, safety, and technological growth. Also, from a global perspective, the safety of men and equipment concerning roof and sides/strata management is one of the pivotal parameters for the success of any technology in under- ground coal mining.

Cause wise analysis of disasters in Indian coal mines since the year 1901(Anon 2020) says that the principal causes of mine disasters had been inundation, fire/explosions, and ground/strata movement. As per the analysis, ground movement (roof and side fall in underground mines and bench failure in opencast coal mines) attributed to 9 disasters between the years 1901 and 2015, involving loss of 114 lives accounting to 5.11% of total fatalities in Indian mine disasters. However, fall of roof and sides in underground attributed to 8 out of 59 disasters and involving loss of 104 lives since the year 1901 up to 2003. It accounts for 4.66% of total 2229 fatalities of Indian coal mine disasters, which is shown in Fig. 1.

In Fig. 1, it explains the number of fatalities on account of disasters due to the falling of roof and sides, occurred in the particular year. The disasters occurred in the years 1923 and 1982 were with 16 fatalities each, which were the highest in numbers.



The study deals with modern strata management, mainly strata control monitoring with analysis of roof–floor convergence, monitored induced stress, and assessment of ultimate mining-induced stress, preferably the vertical component during final extraction in a bord and pillar conventional Indian underground coal mine, Govinda Colliery, a mine of South Eastern Coalfields Limited (SECL), Coal India Limited. Assessment of ultimate mining-induced stress is validated with numerical simulations using FLAC3D software Itasca (2018). The objective of the research study is to develop a conceptual model/roof fall warning index, based on critical strata movement during coal extractions. By these men and equipment can be withdrawn to safe zone, in time, which in turn may lead to a better safety management. Ground control and prevention of accidents due to fall of roof and sides during underground coal mining continues to a matter of great con- cern for mining professionals, and field geologists and this study is related to the same. The output of this research may help the mining practitioners to anticipate dangers relating to roof and side fall during bord and pillar extractions, enabling adequate preventive measures against the same.

Model preparation

A panel of 56 pillars in seven rows has been modeled. The model was discretized by considering tetrahedral elements. The size of each pillar is 22 × 22 × 3 m with the width of the gallery, 4.2 m. The immediate roof of the model was made of hard sandstone of 4 m thick. Above it, formations of 0.5 m of shale and 18 m of sandstone were also assigned in the model, and all such roof layers were separated by interfaces. The floor of the model was considered to be of sandstone of 30 m below the coal seam.

Properties assigned

Coal was considered as Mohr-Coulomb, strain softening material. Main roof and floor of the model were considered to be elastic. Models of different w/h ratio have been constructed and simulated by applying the displacement in an increasing manner at the top. The results concerning average stress and strain have been accessed under various combinations of the strength properties (c and φ) and have been calculated by pillar strength formula given by Jaiswal and Shrivastava (2019), given below. The formula has been derived based on the numerical study conducted on cases of different Indian coal mines.

Pillar strength = [$\sigma^{0.66}$ ¿ 2.39] × [0.36(w/h) + 0.64]

Calibration of the model and strength properties has been done in such a way that the result of the modeling for different w/h ratio shall reasonably match with the value, assessed by above-mentioned pillar strength equation.

Goaf was considered as linearly elastic as suggested by Jaiswal et al. (2014), and Young’s modulus was expressed by the following mathematical relationship.

$E = 1970\exp^{-7.4I/10000}$

where

Table 5 Geo-mining input parameters of cavable roof formations for numerical simulation

Sl. no	Parameters	Details
1	Depth of cover	111 m
2	Working thickness	3 m
3	Pillar size	22 × 22 m
4	Gallery width	4.2 m

E = Young’s modulus

I = Cavability index
The physico-mechanical properties used in the model were shown in Table 6.

Boundary conditions
The bottom of the model was restricted in the downward di- rection whereas sides were restricted in the normal direction. Load of the overlying strata was applied on the top of the model in BZ^ axis in the downward direction. The grid of the model has been uniformly discretized with an aspect ratio of 1.

Stress initialization
Vertical stress has been initialized in the model as per formula is given below:
$\sigma_v = 0.025H$
Horizontal stresses have been estimated by using the Sheorey formula (Sheorey et al. 2001) as given below:
$\sigma_h = \sigma_v[\nu/(1-\nu)] + [\beta EG/(1-\nu)] \times [H + 1000]$
where σ_v is the vertical stress, σ_h is the horizontal stress, and H is the depth of cover.
Feeding the values of parameters in the above equation, i.e., $\nu = 0.25$, $\beta = 3 \times 10^{-5}$/°C, E = 2000 MPa, and G = 0.03 °C/m, the generalized horizontal stress formula can be represented as follows:
$\sigma_h = 2.4 + 0.01H$ (MPa)

Results
As a discrete observation, sides of the pillars near goaf edge were more influenced by the induced stress concerning the core of the pillars.
The simulation, as Figs. 9 and 10, shows the ultimate induced stress of 9.12 MPa at its peak just before the second main fall. The Fig. 11 shows the failure/yield profile in the working geometry, discretizing the shear failure zone of about 4.5 m on either side of the corner of the pillar along the diagonal line of extraction, facing the goaf line, just before the main fall. As a discrete observation, corners and sides of the pillars near goaf edge were more influenced by the induced stress concerning the core of the pillars

Conclusion
The study was related to apprehension/anticipation of strata movement during periods of dynamic loading under bord and pillar extractions. Mining-induced stress reaches to a peak during depillaring before main fall occurs and becomes ultimate. Such ultimate induced stress is also influenced by several other mining parameters which include the following:
(i) Geo-mechanical parameters like area of exposure, area of fall, capability index, and dynamic loading zone
(ii) Parameters on mine geometry, such as height of extraction, depth of cover, and size of pillars
(iii) Physico-mechanical properties of capable rock formations, including UCS of roof rock, rock density, tensile strength, Poisson's ratio, coefficient of cohesion, internal angle of friction, and Young's modulus
(iv) Strata control instrumentation parameters, such as dilation, convergence, load, and stress
Understanding dynamic loading characteristics and anticipation of roof falls along with influence of all the above-mentioned parameters is a difficult task to materialize. Development of the conceptual model/roof fall warning index is an effort for integration of all these. The critical strata movement during depillaring at Govinda Colliery was anticipated with worked out roof fall warning index, which also includes correlation of events with responsible input parameters. Summarily, as per the study, the value of roof fall warning index (C), generalized as more than 3000, can be accorded for anticipation of critical strata movement, leading to a main/ major fall in the – 1 rise depillaring panel at Govinda Colliery in the given set of geo-mining situations, including capability index range of 2000–5000. This derivation of roof fall warning index can be taken into further studies to establish different limits under types of geo-mining situations.

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