International Journal of Coal Geology 98 (2012) 62–72

Contents lists available at SciVerse ScienceDirect

International Journal of Coal Geology

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

Prediction of the height of destressed zone above the mined panel roof in longwall coal mining

Abbas Majdi [a,*], Ferri P. Hassani [b], Mehdi Yousef Nasiri [c]

[a] School of Mining Engineering, College of Engineering, University of Tehran, Tehran, Iran
[b] Department of Mining and Materials Engineering, Faculty of Engineering, McGill University, Montreal, Canada
[c] Khavar Tunnel Consulting Engineering Inc., Tehran, Iran

ARTICLE INFO

Article history:
Received 27 January 2012
Received in revised form 7 April 2012
Accepted 7 April 2012
Available online 18 April 2012

Keywords:
Longwall mining
Height of destressed zone
Mathematical model
Caving zone
Fracturing zone

ABSTRACT

Longwall mining is one of the most widely used underground mining methods most suitable in relatively flat-lying, thick, and uniform coalbeds. Due to extraction of the coal seam, the panel roof strata above the mined zone will be destressed and then the roof loads will be redistributed and transferred to the front abutment and neighboring solid sections with higher load bearing capacity where the adjacent access tunnels and the corresponding barrier pillars are located. The height of destressed zone (HDZ), in this paper is taken as equivalent to the combined height of the caving and fracturing zones above the mined panel roof induced due to longwall mining. The height of destressed zone plays a vital role in accurate determination of the amount of loads being transferred towards front abutment and panel sides. The paper describes the mechanism of development of the height of this zone. Finally, five new simple, yet conclusive, mathematical approaches to estimate the height of destressed zone are presented. The results of the methods proposed are compared with each other and with the comparable methods. The methods proposed are further compared and verified with in-situ measurements reported in the literatures. The comparative results confirm the agreement that exist among the methods and those with the in-situ measurements as well. Finally the methods have shown that, in short term, the height of destressed zone ranges from 6.5 to 24 times the extraction coal seam height; while, in long term, the height of destressed zone ranges from 11.5 to 46.5 times the extraction coal seam height. Therefore, beyond this height the overburden pressure will be transferred towards the front abutment, the adjacent access tunnels, the intervening barrier pillars as well as the panel rib-sides.

1. Introduction

Longwall mining is one of the most widely used methods in underground coal extraction. One of the most important advantages of this method is the automated form of underground coal mining characterized by high efficiency. The main objective of coal mining is to economically extract coal and safely remove them from the ground. Hence, the mining efficiency solely depends on the coal seams overall conditions. In this method, due to the extraction of coal seams within a considerable panel width, after advancing the hydraulic jacks or powered roof supports, the immediate roof of the mined panel is unsupported and hence is allowed to collapse and cave in some distance behind the hydraulic jacks or in the goaf area. The downward movement of the roof strata then gradually extends upwards and will cause the disturbed roof strata to become destressed. Thus, the overburden pressure above the destressed zone will be redirected towards the front abutment and the two adjacent neighboring solid sections where the gate roads (access tunnels serving the coal face), the intervening barrier pillar and the adjacent un-mined solid sections are located. The upward extension of destressed zone (HDZ) depends on a variety of parameters such as: depth, thickness of the extracted coal seams, panel width, the number and the relative thickness and the strength of the panel roof strata and the corresponding coefficient of expansion.

Nowadays, the prime concerns of many coal mining researchers are to find the appropriate approaches to appraise the panel roof strata behavior during and after panel extraction. Professional mining engineers who are dealing with the longwall mining design need to effectively determine the height of destressed zone above the panel roof that induced due to longwall mining. The height of destressed zone (HDZ), in this paper, is considered to be equivalent to the combined height of the caving and the fracturing zones that exist above the mined panel roof. To suitably evaluate the amount of transferrable loads to the adjacent tunnels as well as the intervening barrier pillars, the height of destressed zone must be estimated accordingly which is the main objective of this paper.

* Corresponding author. Tel.: +98 514 398 2215.
E-mail addresses: amajdi@ut.ac.ir (A. Majdi), ferri.hassani@mcgill.ca (F.P. Hassani).

0166-5162/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.coal.2012.04.005

2. Existing views of mined panel roof caving and fracturing appraisal

Longwall mining is a highly productive underground coal mining technique whose basic principles have been traced to the latter part of the 17th century to Shropshire and other counties in England (Anon, 1995). When a longwall panel is extracted then the immediate roof strata are allowed to move downward. Due to the roof strata's downward movements the original natural in-situ stress regime and the hydraulic conductivity will be changed. Hence the roof strata will collapse and fall into the extracted panel space. Depending up on the volume expansion of the fractured rocks, the movements will gradually influence the rock layers above the immediate roof strata. The roof strata will behave differently, depending upon many factors including: strength, thickness and the number of roof rock layers and the thickness of the overburden in all, in one hand, and the extracted coal seam height, the panel width and the panel length, on the other hand. The behavior of the panel roof strata and the process of the gradual upward movement have been of prime concern and hence investigated by many researchers to account for the observed movement as well. The following outlines various literatures, in particular, those by Chekan and Listak (1993); Chuen (1979); Denkhausi (1964); Dinsdale (1935); Eavenson (1923); Hasenfus et al. (1998); Kenny (1969); Luo (1997); National Coal Board (NCB) (1975); Palchik (1989); Peng (1992); Peng and Chiang (1984); Richard et al. (1990); Ropski and Lama (1973); Singh and Kendorski (1981); Styler (1984); Wiggill (1963); Zhou (1991); and many others whose work will be referred later in this paper, wherever they apply.

Eavenson (1923) believed that the inner-burden shear failure during multiple seam extraction in longwall mining extends to the ground surface. Dinsdale (1935) proved that the height of destressed zone (dome) is directly proportional to the depth of cover and to the excavation width and inversely proportional to the horizontal reaction. Wiggill (1963) depicts the concept of a composite destressed zone (dome) and trough theory, where the movement trough does not start from the face but from higher up at the dome boundary. According to Denkhaus (1964), in treating the problem a distinction should be made between sufficiently cohesive rock and insufficiently cohesive rock. For a dome with sufficient cohesion, the maximum height is equal to 50% of the depth of cover above excavation. If the rock is insufficiently cohesive, then the maximum height is 63% of the depth of cover above excavation. Kenny (1969) discussed a method of quantifying the description of the caving zone by means of simple observations and measurements along with the relevance of the manner of caving to roof control. Ropski and Lama (1973) used the terms of primary and secondary regions of caving while working coal seams by longwall mining. The latter authors showed that regions of primary and secondary caving extend to a height of 3–3 · 5 times the thickness of the coal seam extracted.

Chuen (1979); National Coal Board (NCB) (1975); and Peng and Chiang (1984) proposed empirical approaches to estimate the height of caving and fracturing zones induced by longwall coal mining based on the large experiences gained from the British coal mines where the method of longwall mining was originated as well as the USA. Singh and Kendorski (1981)have found that there are three distinct zones (caved zone, fracture zone and continuous deformation zone) of disturbance in the overburden strata in response to longwall mining. Singh and Kendorski (1981)further suggested that the height of caving is dependent on the extracted coal seam thickness as well as the strength and stratigraphy of the roof strata, generally extending upwards 3 to 6 times the thickness of the mined coalbed. Karmis et al. (1983) have indicated that the height of the caved zone can be 12 times the underlying coal seam thickness. According to Styler (1984) measurements of inter-burden deformations above 6 longwall faces, 5 in the United Kingdom, and 1 in the U.S.A. showed that the caving height above a longwall face is equal to 8 to 12 times the extraction seam height, with a zone of fractured rock extending to approximately 50 times the extraction height above the seam.

Peng and Chiang (1984) differentiated four zones in the overburden when a wide enough longwall coal panel is mined; Caved Zone: the immediate roof caves irregularly, filling the void. The strata lose their continuity and bedding planes disappear. Fractured Zone: Located over the caved zone, its main feature is the loss of continuity and breaking or yielding of materials but some bedding planes may remain. Continuous Deformation Zone: In which strata bend downwards without breaking. Only occasional tension cracks can be observed. Soil Zone: The surface layer, whose behavior is very site-dependent. According to Peng and Chiang (1984) the first two zones can be considered plastified, that is, their forming materials yield and hence they can be simulated by means of an elasto-plastic constitutive model. Fawcett et al. (1986) based on their personal communication with Farmer (1980) quoted an alternative formula which is based on the panel width rather than the extraction thickness, predicts greater fracture heights at typical widths between 100 and 200 m.

Palchik (1989) has found that there are three distinct zones (caved zone, fracture zone and continuous deformation zone) of disturbance in the overburden strata in response to longwall mining. According to Palchik (1989) the thickness of the fractured zone varies greatly from 20 to 100 times the seam thickness. The zone above the fractured zone is the continuous deformation zone where there are no major fractures. The extent of the zones of rock movement over longwall mining may vary significantly.

According to Richard et al. (1990) as the mine roof is allowed to collapse, there is an area of caving and severe fracturing which occurs directly above the mined coal seam. This area extends upwards 30–60 times the coal seam thickness, depending on the mechanical qualities of overlying rock strata. Strata sag above the caved area. A “zone of continuous deformation” may extend to approximately 50 ft of the ground surface, depending on the geomechanical properties of overburden layers. This zone is characterized by intermittent fracturing, bedding plane separation, and some sliding of beds across each other. A near surface zone comprising the upper 50 ft of overburden may show increased fracturing or permeability because of compression and tension. Richard et al. (1990) further quoted an interesting study included subsidence monitoring, time domain reflectometry, static water level observations, and hydraulic conductivity in test wells, pre-mining and post-mining coring, and seismic surveys conducted in Virginia coal mines which was reported by Hasenfus et al. (1998); four distinct zones were identified in the panel roof rock strata due to coal seam extraction: Zone 1, the gob zone, just above the mined panel and extending upwards 4 to 6 times the mined seam thickness, Zone 2, the highly fractured zone, above zone 1 and extending to about 30 times the seam thickness is a transitional, highly-fractured zone with massive block-type caving and vertical fracturing. Zone 3, the composite beam, extending from above the highly fractured zone to within 50 ft of the surface, exhibits little vertical fracturing and occasional horizontal slippages between strata. Zone 4, the surface zone, comprises the uppermost 50 ft. Strata in this zone are susceptible to fracturing and movements.

Zhou (1991) believes that the height of caving and fracturing zones follow a geometric function of the height of mining based on extensive field measurements and then modified the empirical equation that was given by Peng and Chiang (1984). According to Peng (1992) the combined height of caved and fractured zones is in general 20 to 30 times the extraction height, being bigger for hard strata and vice versa.

Booth and Spande (1992) suggest that due to longwall mining, different forms of deformation at various levels within the overburden will induce hydraulic changes accordingly. The latter authors believe that there are three different zones of deformation above longwall panel: the first zone is intensely fractured and tends to dewater into the mined panel itself and extends typically up to 20–60 times the mined thickness; the second zone is the intermediate levels of the overburden which subside more coherently and commonly remain a confining layer, and the third zone is the shallow, near surface