Review

Conventional approaches for assessment of caving behaviour and support requirement with regard to strata control experiences in longwall workings

G.S.P. Singh*

Department of Mining Engineering, Indian Institute of Technology (Banaras Hindu University), Varanasi 221005, India

ABSTRACT

Effective control of roof strata is very important for trouble free operation and regular face advance in mechanised longwall workings. It is now technically possible to exploit coal seams in difficult geo-mining conditions with the help of newer innovations in longwall face machineries. A reliable assessment of caving behaviour and support capacity requirement helps in selecting supports of adequate capacity and making operational preparedness for timely and confident solution of impending problems. This paper reviews the mechanism of roof caving and the conventional approaches of caving behaviour and support requirement in the context of major strata control experiences gained worldwide. The review shows that a number of approaches are being used for advance prediction of caving behaviour and support capacity requirement in a variety of geo-mining conditions. The theoretical explanation of the mechanism of roof caving and the design function of roof supports have been worked out through staged development of approaches, their evaluation followed by their gradual modification and enrichment of synthesized findings. This process is still continuing with consistently improved understanding through growing field experiences in the larger domain of geo-mining conditions and state-of-art strata analysis and monitoring techniques. These attempts have contributed significantly to improving the level of understanding and reducing the gap of uncertainty in planning and design of longwall operation in a given geo-mining condition.

1. Introduction

Strata mechanics in longwall mining has been a grey area of research since its introduction to underground coal mining industry worldwide. A number of approaches based on theoretical analysis and field experience have been developed to address the problems of roof control including prediction of caving behaviour and support capacity requirement for safe and sustainable working of a longwall panel. Theoretical models for prediction of main fall and periodic caving span are based on plate-beam theory (Obert and Duvall, 1967) and bending moment approach (Majumdar, 1986). A number of empirical models have been developed on the basis of either certain concept or some field experience to assess the caving behaviour of strata. Some of these approaches suggested roof classifications for qualitative assessment of caving

behaviour (Zamarski, 1970; Arioglu and Yuksel, 1984; Zhao, 1985; Peng et al., 1986, 1989). Some other models proposed quantitative relation to predict the span of main fall (Pawlowicz, 1967; Bilinski and Konopko, 1973; Singh and Singh, 1979, 1982; Unrug and Szwilski, 1980; Peng and Chiang, 1984). Similar relations have been proposed by various researchers to estimate the span of periodic caving (Kuznetsov et al., 1973; Peng and Chiang, 1984; Sarkar and Dhar, 1993; Sarkar, 1998). A few models gave both the options of the qualitative assessment of roof caving and the quantitative assessment of caving span (Ghose and Dutta, 1987; Sarkar and Dhar, 1993; Sarkar, 1998).

Theoretical models for support capacity estimation have been suggested by Terzaghi (1965) and Evans (1975) based on soil mechanics approach. Empirical models have been proposed by Barry et al. (1969), Ashwin (1975), Wade (1976), Josien and Gouilloux (1978), Qian (1982), Peng and Chiang (1984), Shi (1985), Budirsky and Martinec (1986), Majumdar (1986), Wilson (1986), Bigby (1987), Peng et al. (1987, 1989), Porter and Aziz (1988), Jackson and Newson (1989), Jiang et al. (1989), Peng (1992), Sarkar and Dhar (1993), Das (1994), and Sarkar (1998).

Singh (2004) and Singh et al. (2004) conducted a performance study of the existing cavability assessment models for estimation of main fall and periodic caving span in longwall panels. The results of

model observed span for 15 longwall panels were compared with the field observed values. The study concluded that a better approach is required to bridge the gap of uncertainty in predicting the caving behaviour of strata. The caving span estimation using empirical approach is not sufficient to assess the progressive nature of caving and a suitable numerical model is required to predict the failure and caving of strata, and support performance with progressive face advance. Empirical and theoretical models are developed based on idealization of many complex mechanisms and are not expected to respond properly due to their inbuilt limitations. It is also felt that any attempt to develop a reliable support capacity estimation model must be integrated with prediction of caving behaviour. It is highly erroneous to predict the support requirement without reasonable assessment of caving behaviour of strata in a given geo-mining condition.

Medhurst and Kevin (2005) proposed a ground response curve for assessment of support performance at a longwall face. It was devised on the basis of data obtained from automatic data acquisition system for leg pressure monitoring, leg stiffness test and routine underground observations. The model was used for projecting the support requirement under a different geo-mining condition at the same mine. These approaches as mentioned in this section have been classified by Trueman et al. (2005) in seven categories: detached block theory, yielding foundation theory, empirical nomograph, load cycle analysis, neural networks, numerical models, and ground response curves. They concluded that the existing approaches offer important contributions towards understanding strata-support interactions, but do not provide effective means of support specification. They proposed an alternative conceptual approach based on load cycle analysis. It is meant for diagnosis of strata-support problems rather than prediction.

This paper reviews the salient points related to the strata mechanics and various other aspects related to this subject and the state-of-art of the existing approaches. A methodological description of the numerical modelling based approach suggested by the authors is also described. The subject matter covered under this section of the course work presents a systematic description of the issues pertaining to assessment of caving behaviour and estimating the support capacity requirement for longwall working in a given geo-mining condition. It covers the rock mechanics issues related to the caving behaviour and rock support interaction and compiles a review of the state-of-art on these subjects as well. A state-of-art of various approaches used worldwide for assessment of caving behaviour of strata is presented. Important aspects for assessment of support requirement are discussed. The requirement of strata control monitoring is emphasized for performance evaluation and better design of mining structures. It is helpful for improving the safety against strata control hazards, and achieving higher recovery of mineral reserve.

2. Potential models for assessment of caving behaviour

The cavability classification of the coal measure rocks in former Czechoslovakia (Zamarski, 1970) considered the average unbroken length of cores to categorise the roof in three types. Regular caving of strata is achieved if its unbroken core length is less than 10.5 cm (category II).

Polish scientists (Pawlowicz, 1967) have developed rock quality index, L, to assess the caving behaviour of strata:

$$L = 0.016 C_s d \tag{1}$$

where C_s is the in situ compressive strength of roof rock in kg/cm^2, and d is the mean discernible thickness of immediate roof strata in cm.

The above formula was improved by correlating the in situ strength test result with its uniaxial compressive strength (UCS) test result obtained in laboratory and establishing an empirical relationship between the UCS of roof rock in laboratory and mean discernible thickness of immediate roof (Bilinski and Konopko, 1973). The final equation was proposed as follows:

$$L = 0.0064 C^{1.7} K_1 K_2 K_3 \tag{2}$$

where C is the UCS of roof rock measured on dry specimens in laboratory (kg/cm^2); K_1 is the in situ strength coefficient, which is 0.33 for sandstone, 0.42 for mudstone, and 0.5 for claystone or siltstone; K_2 is the creep coefficient, which is 0.7 for sandstone and 0.6 for mudstone, clay stone or siltstone; K_3 is the in situ water content coefficient, which is 0.6 for sandstone with 50% relative humidity, 0.4 for clay stone and mudstone with 50% relative humidity.

Based on the value of L, the roof is categorised in six groups having different values of allowable area of exposure. Good caving of strata is achieved up to a value of L equal to 130 (Class IV roof). A relation has also been established between the span of main fall (S_m) and the roof quality index (L):

$$S_m = 4.47 L^{0.4} \tag{3}$$

2.1. Plate and beam model

Obert and Duvall (1967) developed an equation, based on theory of plates (Timoshenko and Woinowsky-Krieger, 1959), for tensile failure of a gravity-loaded plate clamped on all edges, simulating the condition of failure of roof during main fall at a longwall face, and computed the maximum tensile stress at failure:

$$\sigma_{max} = \frac{6\beta\gamma_e a^2}{t_p} \tag{4}$$

where σ_{max} is the maximum tensile stress (MPa); β is the empirical constant (Table 1) based on ratio b/a (Timoshenko and Woinowsky-Krieger, 1959); b is the longer lateral dimension of the plate (m); a is the smaller lateral dimension of the plate (m); t_p is the plate thickness (m); and γ_e is the effective unit weight of rock (MPa/m), which can be calculated by

$$\gamma_e = \frac{E_1 t_1^2 \sum_{i=1}^{n} \gamma_i t_i}{\sum_{i=1}^{n} E_i t_i^3} \tag{5}$$

where E_i is the Young's modulus of the ith rock layer, γ_i is the unit weight of the ith rock layer, and t_i is the thickness of the ith roof layer.

Eq. (5) is utilised for the purpose of extra loading to the weighting roof layer when the thickness of the upper roof layer is lesser than that of the lower layer.

For a value of $b/a > 2$, the effect of smaller lateral dimension becomes negligible. In such cases, Obert and Duvall (1967) suggested to apply the beam formula presented as follows:

Table 1
Values of β for different values of b/a.

b/a	β
1	0.0513
1.25	0.0665
1.5	0.0757
1.75	0.0806
2	0.0829
>2	0.0833

$$L_b = \sqrt{\frac{2\sigma_t t}{\gamma_e}} \tag{6}$$

where L_b is the failure span of the beam (m), σ_t is the rock tensile strength (MPa).

2.2. Cantilever model

Mukherjee (2003) used an expression for bending moment of a cantilever to compute the span of failure for cantilever, which simulates the condition of roof failure during periodic weighting at a longwall face:

$$L_p = \sqrt{\frac{\sigma_t t_b}{3\gamma}} \tag{7}$$

where L_p is the span of periodic weighting (m), t_b is the bed thickness (m), and γ is the unit weight of rock (MPa/m).

Kuznetsov et al. (1973) proposed an equation to find the critical length of the periodic caving cantilever block:

$$\left(\frac{L_s}{h_s}\right)^2 = \frac{2\sigma_t}{3\gamma H_0} \tag{8}$$

where L_s and h_s are the length and thickness of the strata, respectively; and H_0 is the thickness of overburden. It was reported that the calculated results gave a good prediction of mine roof caving in former Soviet Union with the discrepancy from field results within 15%–20%.

Peng and Chiang (1984) proposed a dimensionally correct method of estimating the span of main fall (L_o):

$$L_o = k\sqrt{\frac{h\sigma_{cf}}{\gamma}} \tag{9}$$

where h is the thickness of immediate or main bed; σ_{cf} is the laboratory UCS; γ is the average unit weight of the bed; k is a constant, roughly equal to 0.25. The span of periodic caving was estimated as half the value of main fall span, i.e.

$$L_p = 0.5L_o \tag{10}$$

Central Institute of Mining and Fuel Research (CIMFR, erstwhile CMRI) of India proposed an empirical and statistical approach to assess the cavability of strata and support rating (Sarkar, 1998). The cavability of the strata is assessed in terms of caving index, I, of the strongest bed existing within the active caving zone:

$$I = \frac{\sigma_c L_c^n t_b^{0.5}}{5} \tag{11}$$

where σ_c is the UCS in kg/cm^2, L_c is the average length of core in cm, and n is the constant depending upon the rock quality designation (RQD) of the bed ($1 \leq n \leq 1.2$).

The caving nature of the roof is classified in five groups depending on the value of caving index, I, of the strongest bed (Table 2).

The approach also estimates the spans of main fall (L_o) and periodic caving (L_p) as follows:

$$L_o = 0.72I^{0.51} \tag{12}$$

$$L_p = 3.05 + 0.25L_o \tag{13}$$

Table 2
Caving index vs. caving behaviour of strata in longwall faces.

Roof category	Cavability index	Caving nature
I	$I \leq 2000$	Easily cavable roof
II	$2000 < I \leq 5000$	Moderately cavable roof
III	$5000 < I \leq 10,000$	Roof cavable with difficulty
IV	$10,000 < I \leq 14,000$	Cavable with substantial difficulty
V	$I > 14,000$	Cavable with extreme difficulty

Singh et al. (2004) proposed an empirical model to estimate the spans of main fall and periodic caving for longwall workings, using the field data of 15 longwall panels and the theory of plate, beam and cantilevers:

$$L_m = 2.71\sigma_m^{0.5} t_m^{0.51} \gamma_e^{-0.32} \tag{14}$$

$$L_p = 1.10\sigma_p^{0.51} t_m^{0.45} \gamma_e^{-0.32} \tag{15}$$

where

$$\sigma_m = \frac{\sigma_t + \sigma_h}{100} RQD \tag{16}$$

$$\sigma_p = \frac{RQD\sigma_t}{100} \tag{17}$$

where L_m is equivalent face advance for main fall (m), σ_m is the effective tensile strength of the main roof (MPa) to be considered for estimation of main fall span, and t_m is the thickness of main roof (m). The average in situ horizontal stress, σ_h (MPa), as estimated by the thermo-elastic model (Sheorey, 1994) of earth crust, does not have any influence upon failure of cantilever strata during periodic caving. Therefore, the effective tensile strength of main roof for estimation of periodic caving span, σ_p, does not consider its influence.

In order to obtain the span of main fall in terms of face advance for failure of the main roof, we calculate L_m using the following equation for different values of assumed face advance for a given face length using trial & error so that it gives the same value of L_m as that obtained from the model (Eq. 14):

$$L_m = 3.46a\beta^{0.5} \tag{18}$$

Apart from the above, a few empirical models have specifically been worked out for longwall top coal caving (LTCC) workings. According to experience gained in China, depth of mining, thickness of the top coal, stone band and the immediate roof, apart from strength and joint frequency of coal, are the major factors that influence cavability in LTCC workings. A parametric study conducted by Jin (2006) yielded the following linear relation:

$$\begin{aligned} I = {}& 0.704 + 0.0006338H - 0.00786C_s + 0.6264C_c \\ & - 0.1797M_J + 0.01434T_c - 0.23056 \end{aligned} \tag{19}$$

where H is the depth of mining (m), C_s is the UCS of coal (MPa), C_c is the coal fracture index, M_J is the stone band thickness (m), and T_c is the top coal thickness (m).

However, a similar study conducted by Humphries and Poulsen (2008) identified depth of mining, coal strength and the top coal thickness as the three most important parameters that influence the cavability of top coal. The resultant expression for cavability index is given by

$$I = -2.64 + 0.0395H - 0.72C_s + 0.6264T_c \tag{20}$$

3. Potential approaches for support capacity estimation

Josien and Gouilloux (1978) suggested that a relation between the desired load bearing capacity P per meter length of face may be obtained using the following equation, by limiting the face convergence to its threshold value of 40 mm/m of face advance:

$$C_vT = (qw)^{\frac{3}{4}}H^{-\frac{1}{4}}\left(\frac{6800}{PM} + 66\right) \tag{21}$$

where C_vT is the average face convergence per meter of face advance (mm/m); w is the working thickness of the seam expressed in meter ($0.8\ \mathrm{m} \le w \le 3\ \mathrm{m}$); q is the subsidence factor: $q = 1$ for caving, $q = 0.6$ for pneumatic stowing, and $q = 0.15$ for hydraulic stowing; H is the depth of the mine in meter ($100\ \mathrm{m} \le H \le 1000\ \mathrm{m}$); PM is the load bearing capacity of the supports in tonne per linear meter of the face ($20\ \mathrm{t} \le PM \le 260\ \mathrm{t}$).

Wade (1976) proposed the following expression for estimation of support load:

$$\text{support load} = 4\gamma h + c_1 + c_2 + c_3 + c_4 \tag{22}$$

where h is the extraction height; c_1 is a factor to consider the effect of hanging immediate roof behind the support. For the thickness of difficult-to-cave layer, $h_2 = 0.3\ \mathrm{m}$, $c_1 = 0$; for $h_2 \ge 0.3\ \mathrm{m}$, $c_1 = 1.33\sqrt{h_2}$, h_1 is the thickness of immediate roof, $h_1 + h_2$ can be less than or more than $4h$. c_2 is a factor for local face activity, $c_2 = 0.5 + W/S$, in which W is the thickness of cut and S is the face span. c_3 is the magnification for bridging of immediate roof thickness (t) prior to first fall, $c_3 = 3.33\sqrt{t}$, c_4 is the magnification for main roof weight.

Shi (1985) proposed the following expression for determination of yield load density:

$$q_H = -3.6 + 5.8M + 1.4L_2 + 3.6l_m \tag{23}$$

where M is the mining height, L_2 is the weighting span of main roof, and l_m is the span of the working space of the working face. The rated yield load density should be calculated considering the support efficiency of 0.65 to 1 for different support types.

Porter and Aziz (1988) made some modifications to the formula suggested by Josien and Gouilloux (1978), replacing the load bearing capacity by the setting load density and introducing geological factor G in place of subsidence factor. They proposed the final equation as

$$C_m = 14\left(\frac{G}{S}\right)h^{0.75}H^{-0.25} \tag{24}$$

where C_m is the mid face convergence in mm/m of face advance; S is the setting load density in MPa; and G is the geological factor for any particular face, its value is 0.7 for competent floor and good caving roof, 1 for floor and good caving roof, and 1.4 for competent roof and floor, heavy caving conditions.

Peng et al. (1989) expressed the characteristics of interaction between the roof and support by using two constants: a and c, and classified the roof into five types. This classification is based on six factors, i.e. thickness of the immediate roof, ratio of immediate roof to mining height, UCS of immediate roof, the type, the thickness and the tensile strength of main roof. Peng (1992) implemented his earlier proposed model (Peng et al., 1989) using a computer programme (DEPOWS) combining the concept of suitability index proposed earlier by Hsiung et al. (1988).

A statistical model (Peng et al., 1989) has also been developed to describe the interaction between the roof and the support. The yield load (P_y) of the support is represented by

$$P_y = \frac{3.2A}{c\eta} + \frac{0.4174aA}{c^2\eta} \tag{25}$$

where η is the support efficiency, A is the support canopy area (ft^2), a and c are the regression coefficients (Fig. 1).

The CIMFR of India proposed an empirical and statistical approach to assess the cavability of strata and support rating (Sarkar, 1998). It correlates the maximum face convergence with the caving index of the strongest bed and the thickness of cavable bed between the coal seam and the strongest bed having the highest value of caving index, I. The projected relation is given as

$$C_m = \frac{A}{P} + 9.6h + \frac{KI}{K' + 1.5} - 23 \tag{26}$$

where P is the mean load density (t/m^2); I is the caving index of the strongest bed; A is a constant depending on rock type, which is 1440 for categories I and II, 1700 for categories III and IV, and 1900 for category V rocks; K' is a factor depending on the ratio of thickness of cavable bed between the strongest bed causing the weighting and the coal seam to the extraction height, $K' = 2$ for ratio up to 2, $K' = 3$ for ratio between 2 and 4, $K' = 5$ for ratio between 4 and 8, and $K' = 10$ for ratio above 8; K is 0.025 for sandstone.

Based on the field observation of face convergence and visual observation observed over hundreds of working cycles in several longwall faces in India, a correlation has been established between the face convergence slope and the degradation of roof at the face as given in Table 3.

With the above consideration, the support resistance P is obtained using Eq. (26), such that the corresponding face convergence is acceptable for safe longwall operation, which is taken as 60 mm/m of face advance.

4. Experiences of longwall strata control

Longwall mining is the most predominant mining method worldwide contributing to as much as 65% of the total underground coal being produced. Nowadays, applicability of longwall is no more limited to medium thick deposits and it is successfully implemented to work thick seams using longwall top coal caving technology in China, Australia and Turkey. Several authors including Ghose and Ghosh (1983), Jain and Roy (1994), Sarkar (1998), Mishra (1984), Mukherjee (2003), and Mukhopadhyay and Kumar (2004) have analysed the scenario of longwall mining in India. The authors have arrived at almost similar conclusions and identified a number of factors including difficult geo-mining condition, improper planning and erroneous selection of support system which are responsible for poor performance of longwall mining and failures.

Salamon et al. (1972) described that geological conditions of coal seams in South African coalfields using longwall mining were overlaid by one or more massive dolerite sill strata. The successful control of the process of caving in these circumstances is a major factor in deciding on the feasibility of longwall mining.

Siska et al. (1983) pointed out that more than 87% of rockbursts were observed at depth more than 600 m in the Ostrava-Karvina coal basin in the former Czechoslovak part of the Upper Silesian coal basin. Schaller and Richmond (1983) observed that in spite of the use of 900 t chock shields and incorporation of the concept of positive set pressure at West Cliff colliery, yielding conditions
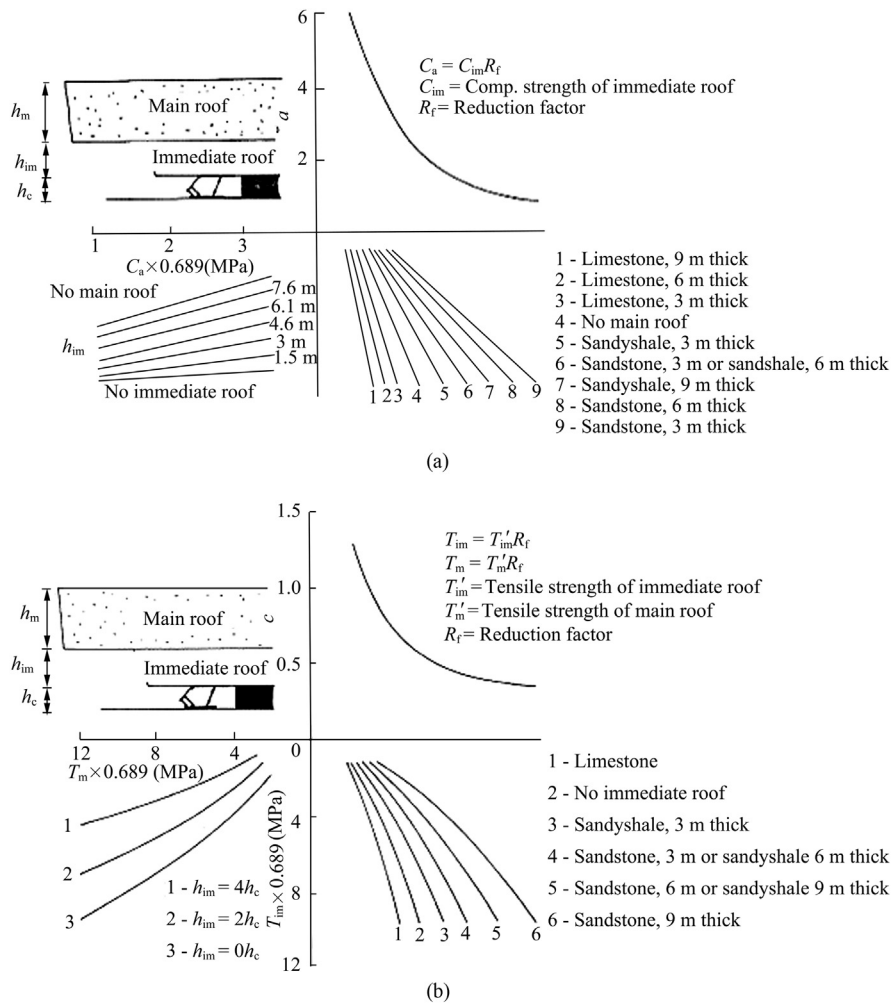
Fig. 1. Nomographs for obtaining values of empirical constants a and c (Peng et al., 1989).

occurred. At Angus Place colliery in the Western district, caving conditions are almost ideal. Initially, longwalls were operating at a cover depth of 70–150 m and the extraction height was 2.6 m in the bottom section of Lithgow seam. However, at a greater depth, the caving characteristics changed and intermittently high roof loads were encountered. The overburden strata in Western district collieries exhibited rapid lithological changes towards more solid sandstone strata. At Appin colliery, the first five longwalls (106–160 m in length) were equipped with chocks of about 600 t yield loads. Whilst the operation in one longwall was successful, four other longwalls experienced major weight at regular or irregular intervals and several chocks attained yield loading conditions. The immediate roof was often prematurely broken at the face line or above the chocks themselves. Many hydraulic legs were leaking

Table 3
Relation between convergence and roof condition (after Sarkar (1998)).

Range of peak convergence (mm/m)	Roof condition
<60	Continuity of roof remains intact with no prominent fracturing
60–100	Minor cracks and breaks and sometimes disjointed blocks are present
100–160	At lower values, prominent fractures are only observed, and rock falls may start occurring at higher ranges
>160	Rock fall causing collapse of the face

and bent owing to lateral movement towards the goaf. The study of roof failure mechanism through field observation and physical model study showed that any kind of roof difficulty is more pronounced if the supports are at a load bearing capacity less than 0.8 MPa. The yield valves are no longer considered to be a protection for the hydraulic components and structures.

Shi (1985) observed that the span of main fall was about 10–30 m in 54% and 30–55 m in 37.5% of the total number of fully mechanized longwall faces in China. Similarly, the periodic caving interval was 5–20 m in 76.5% of the faces. Aziz and Porter (1985) conducted strata control investigation in longwall panel #2 in Bulli seam of West Cliff mine in the Illawara coal region and concluded that high rating powered supports are a pre-requisite for meeting longwall support requirements under competent strata formations. In Datong coal mine, an earth tremor was detected with the seismic shock of 3.2 in magnitude and 4–5 in violence on the surface, when the roof consisting of 4.5 m thick sandy conglomerate and 50–100 m thick sandstone caved in after a goaf exposure of 151,000 m² (Xu, 1985).

Porter and Aziz (1988) conducted strata control investigations at longwall faces in the Illawara region of New South Wales, Australia and Scottish area of the British coalfields. The study concluded that heavy geological conditions of the Illawara region required use of higher capacity supports. Follington and Isaac (1990) observed intermittent dynamic loading of powered supports particularly after periods of face stoppage at panel H65 in Cotgrave coal mine in

South Nottingham coalfield. The study concluded that orientation of face line relative to local and regional geological discontinuities has a clear influence upon excavation stability.

Linden (1999) noted that specific roof conditions in some mining districts in the USA and with increasing importance in Australia, South Africa and India may cause, on certain occasions, extremely high forces being imposed on the powered supports. These high forces occur when massive immediate roof layers or main roof layers suddenly break behind the supports after having hung over a considerable distance. The rapid release of energy during this failure process requires the supports to rapidly yield in order to avoid destructive overload conditions. Hatherly and Luo (1999), and Hamilton (1999) suggested that in certain longwall faces, where the occurrence of massive overburden strata causes frequent face instability and danger of air-blast, effective air-blast management plans including personnel protection to prevent injuries, seismic monitoring for pre-warning of air-blast events to evacuate the workings, and hydro-fracturing of the strata by injecting water from the face into the roof should be sought, as tried in some of the Australian coal mines. If hydro-fracturing can be developed as a reliable tool, air-blast event would no longer be unpredictable and the magnitude of major roof caving and intensity of resulting air-blast can be reduced.

Deb (2000) noted that the intensity of periodic load on support is high particularly at the inflection regions where the floor changes its slope and also in the presence of surface lineaments. Heavy loads were observed on the support structures of over 10 MPa yield capacity, whenever massive roof layers caved over a large goaf area in the longwall face of 130 m face length at Matla mine of South Africa (Woof, 2001). The span of main fall was 60 m. Rapid yield valves were designed to respond quickly allowing the supports to close at a speed of 440 mm/s, equivalent to a fluid bleed rate of 3500 L/min. Most of the cylinders were fitted with either stroke or pressure sensors to monitor actual conditions constantly and provide feedback to the automation loops.

5. Conclusions

Predicting the caving behaviour of strata and the support capacity requirement for safe working in longwall is a complex issue and requires utmost care in such studies. A considerable number of approaches have been developed, evaluated, modified and again re-evaluated. This process has been continuing till now with the help of field experience, day to day growing computation power and state-of-art field monitoring techniques to improve the level of understanding and reducing the gap of uncertainty in planning, design and equipment selection for longwall mining operation in a given geo-mining condition. Empirical models are over-simplification of the complex system and therefore should be used only for making the first hand estimate in relatively well explored locales where adequate field experience is already available. An appraisal of these approaches shows that a universally acceptable approach is yet to be developed for a rational and reliable design methodology for prediction of caving behaviour and optimum capacity support selection. The task becomes complex due to variation in geological texture, strength, joint distribution network of rock mass and typicality of in situ stress field from one origin to another. However, it is a well realized fact that there is no softer option than longwall technology for working coal seams at greater depths to meet the huge demand of coal. In-depth and more scientifically valid study can be made using advanced approaches available for this purpose for a complete resolution of all relevant concerns.

Conflict of interest

The author wishes to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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Gauri Shankar Prasad Singh is an assistant professor of Mining Engineering at the Indian Institute of Technology (Banaras Hindu University), Varanasi, India. He has been involved in research, consulting and education for more than 15 years. Apart from earning two patents, he is the author or co-author of more than 60 scientific papers published in several international and national journals and conference proceedings. His major areas of research interest include strata control, support design, and numerical modelling study for underground mining structures. He has also been associated with research projects related to induction of caving using high pressure water injection and deep hole surface blasting in underground coal mines. In recent years, he has been awarded best researcher award of IITBHU Alumni Association in its first category for two consecutive years. He is a member of International Society for Rock Mechanics and a life member of the Mining, Geological and Metallurgical Institute of India and the Mining Engineers Association of India.