Pillar design in coal mines

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SYNOPSIS

The paper points out that bord-and-pillar mining is the most important method of coal extraction in South African underground coal mines, and advocates that pillar design procedures should be refined to make more rational allowance for the differences in strength properties between various coal seams and roof and floor strata. However, any deviations from well-established design procedures must be based on sound engineering principles and reliable data on the strength properties of the seams and strata concerned. Recent information indicates that practices for the protection of surface structures against underground mining should be revised.

SAMEVATTING

Die referaat wys daarop dat die kamer en pilaar metode van afbou die belangrikste metode vir steenkoolontginning in Suid-Afrikaanse ondergrondse steenkoolmyne is en bepleit die verfyning van die pilaarontwerpprosedures om meer rasionele voorsiening te maak vir die verskille in die sterkte-eienskappe van verskillende steenkoollae en dak- en vloerstrata. Enige afwykings van die gevestigde ontwerpprosedures moet egter op gesonde ingenieursbeginsels en betroubare data oor die sterkte-eienskappe van die betrokke lae en strata gegrond wees. Die jongste inligting dui daarop dat praktyke vir die beveiliging van bogrondse strukture teen ondergrondse mynbou hersien behoort te word.

Role of Bord-and-pillar Mining

A recent study by King[1] has shown that, despite the increase in relative importance of open-cast and longwall mining methods, bord-and-pillar mining is likely to remain the most important method of coal extraction for many years to come.

Compared with the other methods of coal extraction, it offers the advantages of great operational flexibility, relative freedom in the sequence of seam extraction, insensitivity to local and regional geological disturbances, maintenance of the integrity of the roof strata and surface, and, finally, low capital intensity. The last-mentioned point is particularly important in an environment of expansion.

The main disadvantages of bord-and-pillar mining are that coal has to be left *in situ* to support the roof strata, and that the labour productivity is relatively low when compared with opencast and longwall mining systems. It is important to note that both the amount of coal being lost in the support pillars, and the labour productivity are dependent on the depth of mining. While the effect of mining depth on the size of pillars, and therefore on the percentage extraction, is generally recognized, the extent to which the increased pillar centre distance affects productivity is often not appreciated. Fig. 1 shows how the percentage extraction and the percentage production efficiency (expressed in tons per face minute) decrease with depth of mining. Another parameter that has considerable importance in bord-and-pillar mining is the seam thickness. The influence of this parameter on the amount of coal lost in the support pillars is shown in Fig. 2, which illustrates clearly how in a conventional bord-and-pillar system the coal losses increase with seam height.

From Figs. 1 and 2 it follows that the area of application of conventional bord-and-pillar mining is restricted by depth of mining and seam thickness. Without any allowance for economic considerations, Fig. 3 attempts to define the potential areas of application of conventional bord-and-pillar mining methods. The alternatives are opencast methods where the coal seams are relatively shallow and thick, and panel and longwall mining methods for deeper coal seams. The area of application of opencast methods is largely determined by the size of the coal deposit and the coal-to-waste ratio. For longwall and panel mining, the areas of application are less clearly defined. The governing factors in this case are the mining costs on the one hand, and the percentage of coal lost in the support pillars on the other. In the preparation of Fig. 3, a 30 per cent loss in *in situ* coal reserves was assumed to be representative of longwall and panel mining methods. This diagram takes into account the relative inflexibility of these mining methods as far as geological disturbances are concerned. For purposes of comparison, lines of 40 and 50 per cent coal losses are included in the diagram. The coal-to-waste ratio line, which dips to the left of the diagram, and the curves showing the percentage of lost coal, which dip to the right, delineate the potential areas of application of conventional bord-and-pillar mining methods.

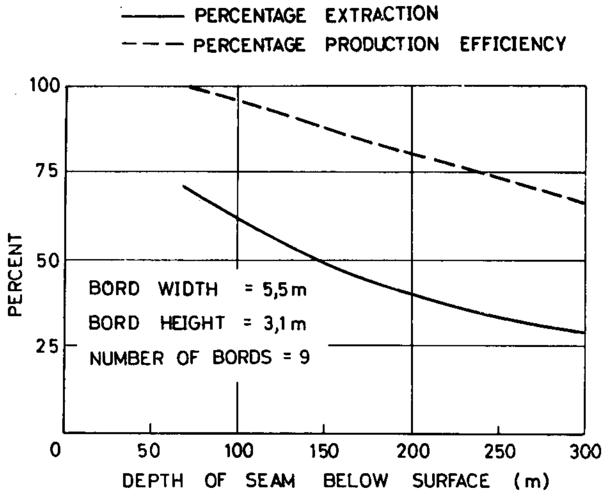

Fig. 1—Effect of depth of mining on percentage extraction and productivity in bord-and-pillar mining

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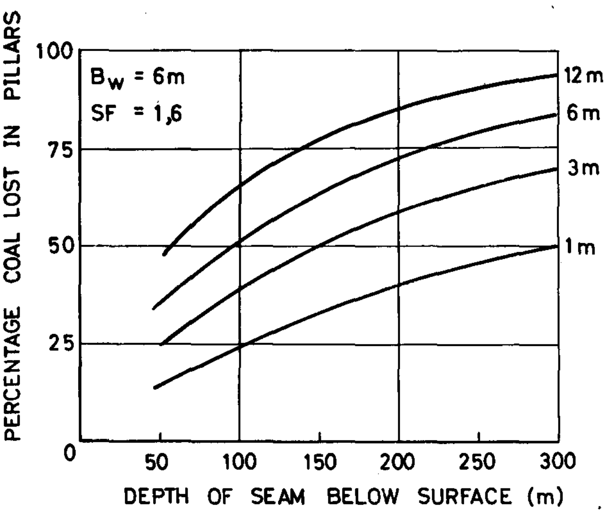

Fig. 2—Effect of depth below surface and seam thickness on coal losses in bord-and-pillar mining

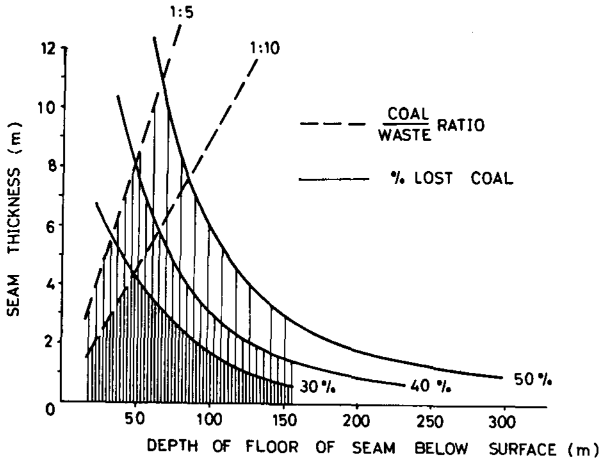

Fig. 3—Potential areas of application of bord-and-pillar mining

It should be noted that both bounds are controlled largely by economic factors. For the most severe constraints, namely a coal-to-waste ratio of 1:10 and an upper limit for lost coal of 30 per cent, the field of application of conventional bord-and-pillar methods is narrowed to seams that vary in thickness from 1 to 4 m and that are situated at a depth ranging from 50 to about 150 m. The latter depth applies to the seam 1 m thick.

According to figures published by the Petrick Commission, about 33 per cent of South Africa's coal reserves fall within this range. If the limits for the application of bord-and-pillar mining methods are widened to a coal-to-waste ratio of 1:5 and 40 per cent lost coal, then almost 63 per cent of the country's coal reserves fall within the scope of bord-and-pillar mining.

From the above discussion it follows that considerable benefit can be gained from a critical examination of the principles underlying the design of coal pillars.

Design of Bord-and-pillar Workings

The design of bord-and-pillar workings is one of the oldest and most difficult problems in coal mining. The difficulties arise from the conflicting requirement that, on the one hand, the size of the coal pillars should be as small as possible to minimize the losses of coal reserves, while, on the other hand, the pillars should remain stable. The design problem is complicated further by the complex loading conditions of coal pillars both locally and regionally, and the natural variations in the properties of the coal seams and surrounding rock strata. It is for these reasons that slow progress has been made in the design of bord-and-pillar workings in coal mines.

It can be said without hesitation that the design procedures that were proposed by Salamon in 1967 and that have been generally adopted by the coal-mining industry in South Africa are by far the most advanced of all known design methods. Two publications provide the basis for the design of bord-and-pillar workings in South African collieries: a summary of the basic principles involved[2] and a set of design tables[3]. Several other publications[4–6] have been issued on the subject apart from those directly referred to later in this paper.

The purpose of this paper is not to replace these publications, but rather to highlight new developments in the field of pillar design and to discuss some of the more intricate problems.

Function of Pillars in Coal Mines

In coal mining, as in any other underground mining operation, two different categories of pillars are encountered: support pillars and protective pillars. The differences between the two categories of pillars are often not clearly visible, and there are indeed a number of instances when pillars fulfil both requirements. However, there are a number of significant differences in the design of the two types of pillars.

Support Pillars

Support pillars can be divided into two classes: pillars that provide local support, and pillars that provide regional support. However, pillars often provide both local and regional support. A good example of this is a conventional bord-and-pillar mining layout that has been designed at a high safety factor. Local-support pillars have often only temporary use and are extracted once they have fulfilled their purpose. This category of pillar is likely to gain in importance in the near future.

One of the interesting aspects of local-support pillars is that their useful function is often limited to the time when actual mining takes place in their immediate vicinity. Subsequent failure to these pillars can take place provided the mode of failure is stable. The concept of yielding support pillars falls into this category and requires further elaboration.

Barrier and wide inter-panel pillars are typical examples of pillars that provide regional support.

Protective Pillars

In the course of mining, it often becomes essential to protect underground and surface structures from the effects of mining. One of the practical means of achieving this is to leave portions of the coal seam unmined to form protective pillars. The design criteria for these pillars depend largely on the nature of the structure that needs to be protected. In the case of surface structures, the design criterion is based on the magnitude of the surface movements and strains that can be tolerated by the structure. In the case of underground structures such as bunkers, pump stations, service excavations, etc., it is usually the magnitude of the stresses that determines the size of protective pillars.

Basic Design Principles

The classical approach to the design of engineering structures is to determine the strength of the structure and to compare it with the stresses acting in the structure. The design procedure is to change the dimensions of the structure or its material properties until the maximum stresses acting in the structure are equal to the strength of the material reduced by a safety factor. The latter makes allowance for slight variations in the strength of the material and uncertainties concerning the magnitude of the maximum stress.

Strength of Coal Pillars

Because of the complex loading conditions in pillar mining and the difficulties in determining the *in situ* strength properties of the pillar material, a somewhat simplified approach is generally adopted in the design of mine pillars. Instead of determining the maximum stress that acts in the pillar, the average pillar stress is commonly used. Also, rather than using the strength of the pillar material, empirical formulae that predict the strength of the whole pillar have been developed. These formulae suffer from the disadvantage that they are valid only for the conditions for which they have been derived.

Since the strength of a pillar is a function of the material strength and the distribution of stresses in the pillar, it is important to examine the factors that influence the latter. Probably the most important factors in this respect are the vertical and horizontal components of the stress vector at the contact between the pillar and the surrounding rock. The distribution of these components and their magnitude are influenced strongly by the friction and cohesion in the contact plane, and by the deformation characteristics of the pillar material and the surrounding rock strata. In 1970 Peng[7], in a series of controlled laboratory experiments, showed that the strength of cylindrical samples made from the same rock type can vary by as much as 100 per cent depending on the conditions at the interface of the rock-sample testing machine. Similar results were obtained by Wagner[8], who simulated the effects of a very soft layer at the contact between pillar and surrounding strata by inserting a thin lead sheath between the platen of the testing machine and the rock sample. These tests showed that the presence of a soft layer not only reduces the strength of the rock sample but also changes the mode of failure of the specimen (Fig. 4). Similar effects can be observed underground, and should be considered when designing support pillars.

Fig. 4—Effects of end constraints on mode of failure of rock samples

Left: interface between rock and steel platen.
Centre: thin lead sheath on both contacts.
Right: thin lead sheath on top contact only.

From the above, it follows that any method of predicting pillar strength must take into account the properties of the pillar material and the surrounding rock strata, as well as the nature of the contact surfaces. This aspect is often neglected, and a number of pillar failures can be attributed directly to the application of empirical formulae for pillar strength under conditions that were not comparable with those for which the formulae were derived. As a general guideline, it is recommended that the design safety factor be increased for pillars in the presence of soft shale bands at the contact between pillar and roof strata.

An important feature of pillars is that their strength tends to increase with their ratio of width, w, to height, h. This increase in strength is due to the lateral confining effect imparted to the pillar by the lateral component of the contact stress. The effect of the width-to-height ratio on the strength of pillars can be expressed by a power law of the following form:

$$\text{Strength}=C.h^{\alpha}w^{\beta}, \quad \ldots\ldots\ldots\ldots (1)$$

where C is the compressive strength of the pillar material and α and β are appropriately chosen constants. An examination of the formulae for pillar strength published by various authors shows that the value of constant α varies from $-1{,}0$ for laboratory pillar tests (Steart[9]) to $-0{,}83$ for moderately large model pillars (Greenwald *et al.*[10]) to $-0{,}66$ for full-size coal pillars (Salamon and Munro[11]). The value of constant β was found to be 0,5 in all the model pillar tests, while Salamon and Munro[11] obtained a value of 0,46 from the statistical analysis of a large number of case histories. It is interesting to note that the effect of the width of a pillar on its strength tends to be independent of the size of the pillars, while the effect of pillar height is greatest in the case of small pillars but tends to decrease with pillar size.

So far, only the effects of two geometric parameters on the strength of coal pillars have been discussed: namely, the width and height of the pillar. The effect of the length of a pillar on its strength is not yet fully understood. It has been suggested that the strength of rectangular and irregular pillars is about the same as that of a square pillar having the same cross-sectional area. On the basis of this assumption, an effective pillar width, w_{eff}, is defined:

$$w_{\text{eff}}=\sqrt{A_{\text{p}}}, \quad \ldots\ldots\ldots\ldots (2)$$

where A_{p} is the cross-sectional area of the pillar.

In a detailed study of the failure process of coal pillars, Wagner[12] showed that the failure commences at the circumference of the pillar and migrates inwards. An interesting observation made during these studies was that, at the time of the overall structural failure of the pillar, the central position of the pillar had not yet reached its full load-bearing potential (Fig. 5). On the basis of these observations it was suggested that the ratio of the area, A_p, to the circumference, C, of a coal pillar has a strong influence on the pillar strength. Accordingly, the effective width, in metres, of a pillar of irregular shape is defined as

$$w_{eff}=\frac{4.A_p}{C}. \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

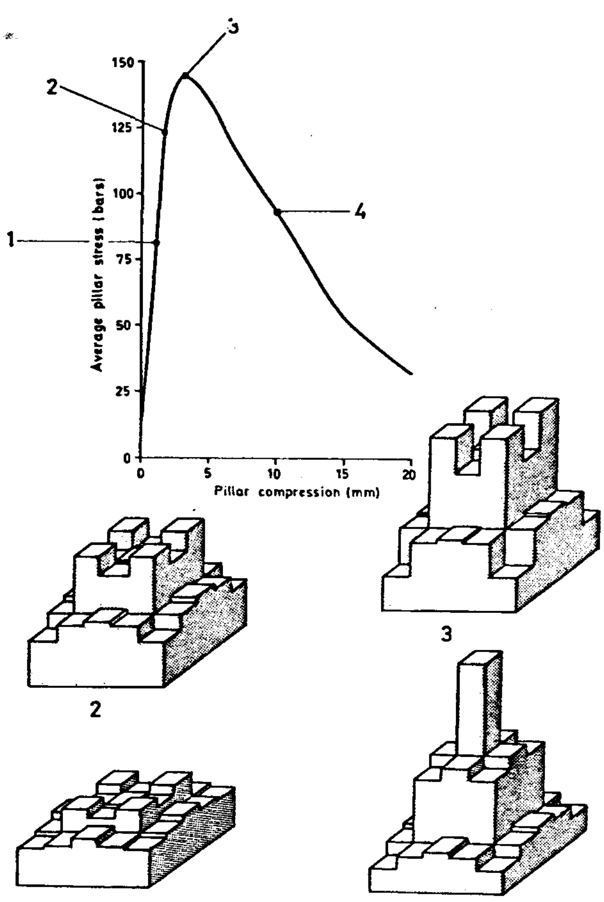

Fig. 5—Stress profiles through a coal pillar measuring 2 m in width and 1 m in height at various stages of pillar failure

Fig. 6 shows that, up to a length-to-width ratio of about 4, the differences between equations (2) and (3) are rather small but become significant for large ratios. According to equation (3), the effective width, and consequently the strength, of a very long rectangular pillar reaches a finite value, whereas equation (2) suggests that the strength of a long narrow pillar continues to increase as its length increases (Fig. 6). Clarification of the effect of the length-to-width ratio on the strength of long rectangular pillars is an important task for the design of barrier and inter-panel pillars.

Another important aspect of the design of coal pillars is the effect of the method of coal winning on the strength of pillars. The formula derived by Salamon and Munro[11] that forms the basis of the design procedures for bord-and-pillar workings in South African collieries is based on the analysis of a large number of case histories of failed and intact coal pillars that had all been formed by drilling and blasting. It is reasonable to assume that the skin of the coal pillar was affected by blasting and lost some of its strength properties. If it is assumed that the effective width of a pillar formed by blasting is reduced by, say, 0,3 m, then the strength of a pillar formed by cutting is greater since the effect of the 0,3 m of coal at the circumference of the pillar has not been taken into consideration.

The likely benefit that is to be gained in terms of pillar strength and safety factors from the use of continuous miners can be estimated from the following expression:

$$S=S_0(1+\Delta w/w_0)^{2,46}, \quad \ldots\ldots\ldots\ldots \quad (4)$$

where w_0 is the nominal pillar width and Δw is the effective increase in pillar width as a result of preserving the skin of the pillar. S_0 is the safety factor based on

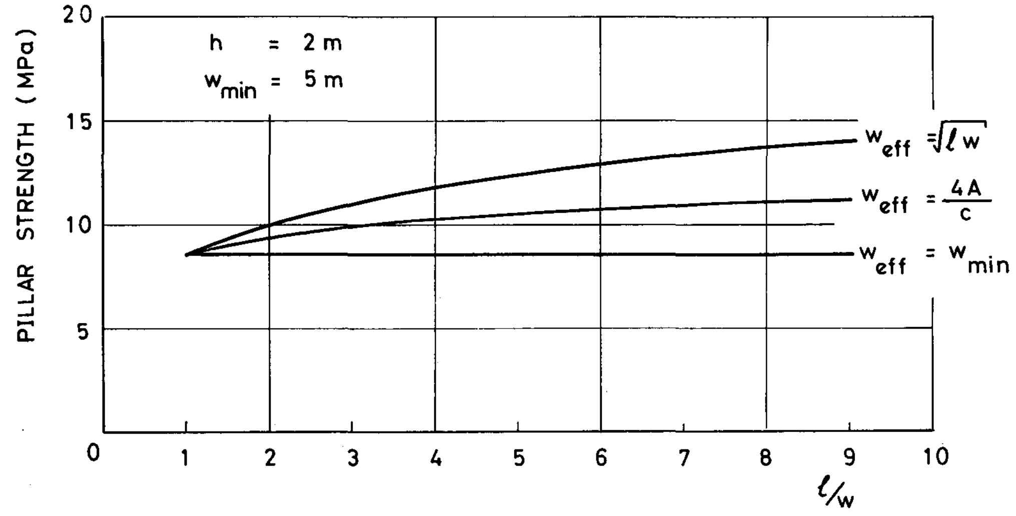

Fig. 6—Effect of length-to-width ratio on the strength of rectangular coal pillars

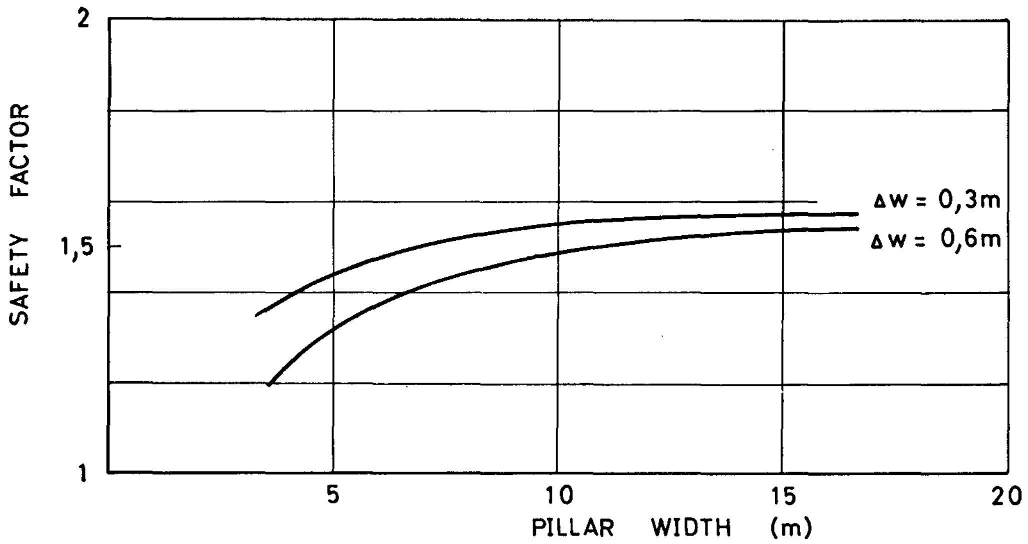

Fig. 7—Influence of pillar width on the potential reduction in design safety factors of mechanically cut coal pillars

the nominal dimensions, and S is the effective safety factor. Fig. 7 shows the benefits in terms of reduced nominal safety factors that are likely to be gained from the use of continuous miners.

The most important conclusion that is to be drawn from Fig. 7 is that the beneficial effects that accrue from the use of continuous miners are greatest for small pillars, but diminish rapidly as the size of the pillars increases. The observation is contrary to the belief often expressed in the mining industry that, as a result of the use of continuous miners, the nominal safety factor can be reduced by a fixed amount regardless of the size of the pillars.

Strength of Roof and Floor

One important aspect in bord-and-pillar mining is the strength of the roof and the floor. Weak roof and floor strata in the immediate vicinity of the coal seam can affect the following in bord-and-pillar mining:

(i) the local roof support in the bords,
(ii) the working conditions and the use of mechanized equipment, and
(iii) the long-term stability of the bord-and-pillar system.

As far as local roof control in bord-and-pillar workings is concerned, the problems tend to increase as the density of the bedding planes in the immediate roof strata increases, or the strength of the rock composing the individual beds decreases. In principle, there are two ways of improving the behaviour of the immediate roof:

(a) by increasing the apparent strength of the roof, and
(b) by reducing the induced stresses in the roof.

The former can be achieved by the introduction of support, whereas the latter concerns mine design and layout. The most important parameters that control the magnitude of the induced stresses are the size of the pillars and the bord width. In general, the magnitude of the induced stresses decreases with increasing pillar size and decreasing bord width. In laminated or bedded roof strata, marked improvements in the quality of the roof can often be achieved with small reductions in bord width. The significance of bord width on the strength of laminated roof strata is best illustrated by a gravity-loaded clamped beam, where t is the thickness of beam and B the bord width. Then the maximum deflection, $S_{\max}$, at the centre of the beam, and maximum shear stress, $\tau_{\max}$, at the end of beam, and the maximum normal stress, $\sigma_{\max}$, at the end of beam are given by

$$S_{\max}=\frac{\gamma B^4}{32\,E\,t}, \quad \ldots\ldots\ldots\ldots \quad (5.1)$$

$$\tau_{\max}=\frac{3\,\gamma\,B}{4}, \quad \ldots\ldots\ldots\ldots \quad (5.2)$$

and

$$\sigma_{\max}=\frac{\gamma B^2}{2t}, \quad \ldots\ldots\ldots\ldots \quad (5.3)$$

where γ is the unit mass of the beam, t is the thickness of the beam, and E is the modulus of elasticity of the beam material.

From equation (5.3) it follows that a change in bord dimensions from 6 m to 5 m results in a 31 per cent reduction in maximum tensile stress in the immediate hangingwall beam. In the author's opinion not enough use is being made of this most effective method of improving roof quality.

The presence of a relatively thin, soft shale band or coal seam in the roof or floor strata of the seams that are being worked can have a significant influence on the quality of the immediate roof or floor, even if these are composed of relatively competent sandstone. An example of excessive floor heave caused by a very soft shale band, sh, beneath an otherwise competent sandstone bed, st, is shown in Fig. 8. Phenomena of this kind are usually confined to relatively deep-lying coal seams. This type of floor heave is often observed in pillar-extraction sections where the situation is aggravated by the high abutment stresses that act on the pillars in the stooping line. In the case of very narrow seams, floor heave can be so severe that it becomes a serious production problem.

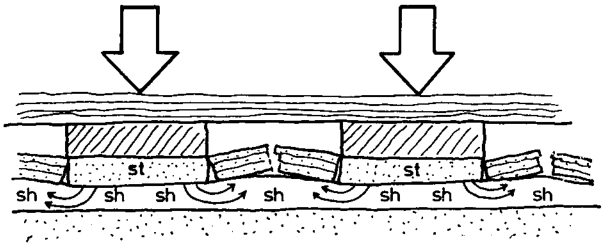

Fig. 8—Effect of a band of soft shale (sh) in the floor strata of a coal seam on the behaviour of the immediate sandstone floor (st)

Probably the most serious long-term problem in the application of bord-and-pillar mining methods is caused by very weak, relatively massive beds in the immediate roof strata. The highly stressed coal pillars tend to punch into these weak beds, resulting in a severe, deep-rooted deterioration of the immediate roof strata that can lead to excessive roof falls and finally a complete collapse of bord-and-pillar sections. This collapse is, however, not caused by a failure of the coal pillars, but rather by a failure of the strata above the pillars (Fig. 9). Experience suggests that this type of pillar collapse takes place over a considerable period and is generally not concurrent with active mining. One possible solution to this kind of structural collapse is to fill the workings, which has the effect of minimizing the vertical extent of roof fracturing.

Pillar Load

The prediction of pillar load is one of the principal problems in the design of pillar layouts. Until recently the only theoretical method of determining pillar load was based on the tributary-area theory. This theory applies to horizontal workings of which the lateral extent is very large in relation to the depth below surface. Under these conditions, the average vertical pillar stress is given by the following equation:

$$p_{\rm m}=\gamma H(A/A_{\rm p}), \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (6)$$

where γ is the mass of rock per unit volume and H is the depth of seam below surface. The area of the pillar is denoted by $A_{\rm p}$, and the corresponding tributary area is denoted by A. The average pillar stress can also be expressed in terms of the extraction ratio:

$$e=(A-A_{\rm p})/A=1-(A_{\rm p}A)/,$$

that is

$$p_{\rm m}=\gamma H/(1-e). \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (7)$$

It is important to note that the pillar stress, $p_{\rm m}$, calculated from equations (6) and (7) represents the upper limit of the average pillar load in any horizontal working of constant height supported by uniform pillars.

In the more general case, that is when the extent of mining relative to the depth of workings below surface is small, the tributary-area theory results in an overestimate of the pillar loads since it does not take into account the effects of solid abutments outside the workings. To illustrate this point, consider a panel of span R that is situated at depth H below surface. Assume that the rock strata surrounding this panel are linearly elastic and that no pillars have been left within the panel. In this case, a certain convergence distribution, $y_{\rm i}$, that is dependent on the elastic properties of the rockmass, the panel span, R, and the depth below surface, H, will be observed within the panel. To satisfy the condition of equilibrium, the mass of the unsupported roof strata above the panel will be redistributed in the form of abutment stresses. Assume now that a number of pillars were left in the panel to support the roof strata. The purpose of these pillars is to resist the convergence between roof and floor that would otherwise take place. Clearly, these pillars will be more effective if they have a high stiffness — that is a large width-to-height ratio. Since the convergence in an unsupported panel is greatest in the centre, it follows that under otherwise identical conditions the load on panel pillars will increase towards the centre of the panel.

Salamon[13–15] has discussed the basic principles of determining pillar loads in the more general cases. A detailed discussion of these principles falls outside the scope of this paper, but, to illustrate some of the more pertinent points concerning the effects of strata and pillar stiffness and of panel dimensions on pillar loads, two specific examples quoted by Salamon[15] are discussed.

Fig. 10 shows the change in pillar loads due to the widening of a panel from 3 to 7 and then to 11 pillars. The average pillar stress, $p_{\rm m}$, according to the tributary-area theory would be 4 Q_{33}, where Q_{33} is the vertical component of primitive stress. This corresponds to an extraction ratio, e, of 75 per cent. It should be noted that, as the panel is widened, the pillar load on the centre pillar approaches 4 Q_{33} more and more closely. This increase in pillar load is due to the reduction in the depth-to-panel span ratio, H/R, which governs the overall strata stiffness.

The second example, Fig. 11, shows how the average stress that acts on the pillars in the central row of a panel containing 5 pillars changes as a function of the $E_{\rm s}/E$ ratio and the H/R ratio. The influence of the pillar stiffness on the pillar loads is obvious from this diagram. The effect of depth-to-panel span ratio on the average pillar stress is less pronounced as indicated by the close proximity of the two H/R curves.

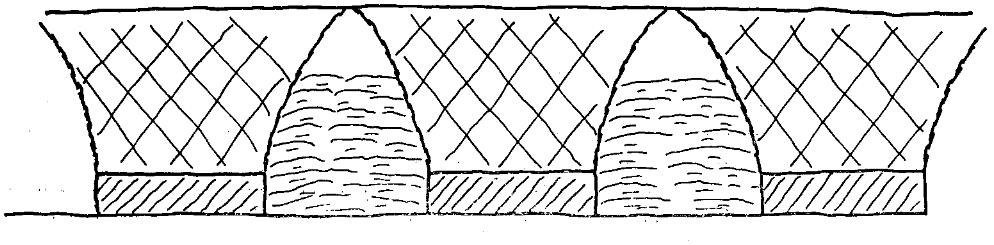

Fig. 9—Regional collapse of a bord-and-pillar section caused by excessive falls of the very friable, massive immediate roof

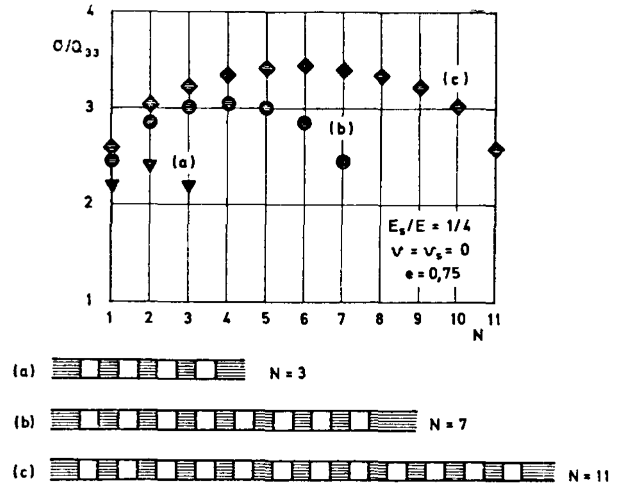

Fig. 10—Increase in panel pillar load due to widening of a panel (after Salamon[15])

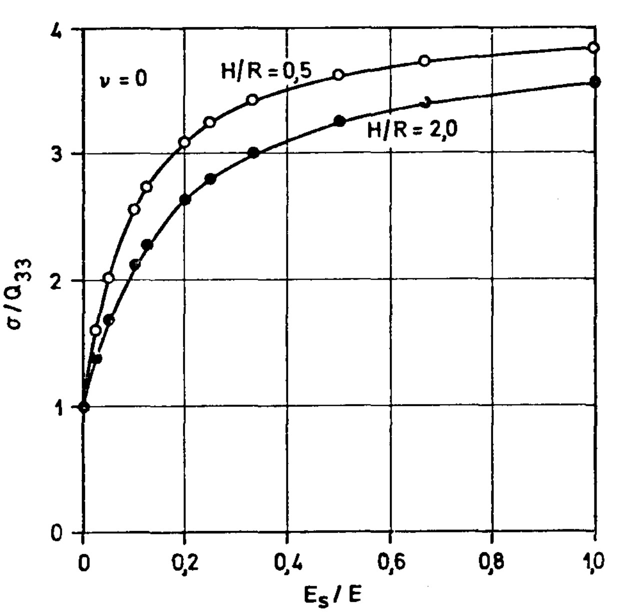

Fig. 11—Effect of relative pillar stiffness, E_S/E, and depth-to-panel span ratio, H/R, on panel pillar load (after Salamon[15])

Although the above examples provide further support to the observation that the design of bord-and-pillar workings on the basis of the tributary-area theory is essentially conservative, a few words of caution are warranted. These concern mining activities in some of the older collieries where seams had been worked a long time ago. All the examples discussed in this section indicate that an increase in the lateral extent of mining will result in an increase in the average pillar loads. This increase will be significant in the case of the widening of relatively narrow panels, but small in the case of wide panels. A further point to consider is that the extraction of substantial island pillars, which act as abutments, can lead to marked increases in the load on panel pillars in old areas. Depending on the safety factors in the workings, pillar collapses that are caused by the removal of island pillars or an increase in the lateral extent of mining cannot be excluded.

Another area of concern is that of so-called experimental panels in which the pillar dimensions are reduced to an extent that the nominal safety factor approaches a value of about 1. Conditions in these panels are often surprisingly good and belie the potential dangers. This is particularly so in the case of relatively narrow panels supported by slender pillars of low stiffness (E_S/E of about 0,3). The situation is aggravated further if competent beds are present in the roof strata. These tend to reduce the E_S/E ratio to even lower values. From Fig. 11 it follows that, at very low E_S/E ratios, the effective pillar load tends to be less than 0,7 of the loads calculated on the basis of the tributary-area theory. In other words, the effective safety factor in these panels is greater than that based on the tributary-area theory. If, however, the panel spans are increased or other panels are being mined, the loads on these pillars will increase and failure is likely to take place. A revision of pillar-design procedures that is motivated by good ground and pillar conditions in experimental panels of limited lateral extent must be warned against.

Protective Pillars

The design of protective pillars differs greatly from that of normal panel pillars. As pointed out earlier, the function of protective pillars is either to minimize ground movement, or to control the stresses that act on underground structures so as to ensure that no excessive damage takes place. In either case, the strength of the pillar is usually not the limiting criterion.

Statutory regulations demand that the width or diameter of pillars for the protection of surface structures should increase with the depth of mining according to the following equation:

$$W_P = W_S + 2H/2{,}7, \qquad (8)$$

or

$$W_P = W_S + 0{,}7H, \qquad (9)$$

where W_P is total width of the protective pillar and W_S is the width of the structure that requires protection. The increase in pillar width with depth of mining is based on the concept of angle of draw, which is assumed to be 70 degrees.

Very limited data exist on surface displacements above relatively narrow pillars that separate panels of high percentage extraction. Most of the available data have been collected in connection with longwall and stooping operations. Fig. 12 summarizes the available information on surface subsidence above isolated pillars. To allow for a better comparison of the data, the pillar dimensions were normalized with respect to depth, and the subsidence figures with respect to the extracted mining height, h. Two important observations can be made from the data presented. First, a very limited amount of subsidence occurs even over very wide pillars and, second, the subsidence above solid pillars increases rapidly once the width of these pillars is less than 0,3 H. To design protective pillars economically and efficiently, it is necessary to define the amount of surface movement that can be tolerated by the structure. For very sensitive structures, the statutory requirements may not be adequate, whereas, for other less-sensitive structures, protective pillars may be over-designed by as much as a

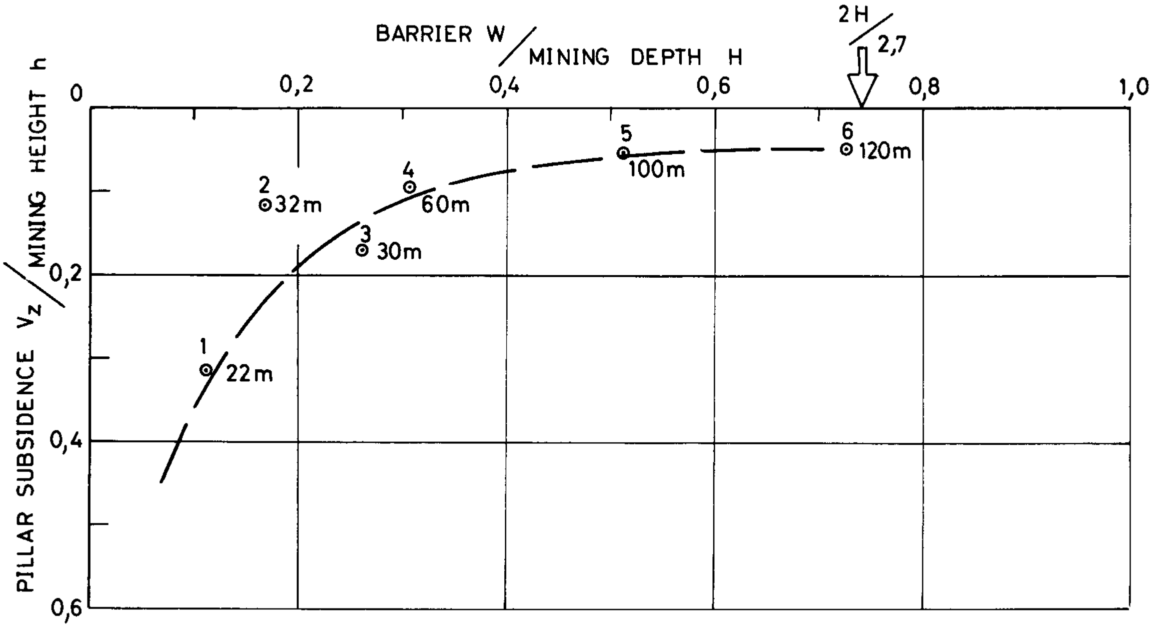

Fig.—12 Normalized surface subsidence above isolated barrier pillars

factor of 2 or 3. In view of the large quantities of coal that are locked by surface restriction, a more flexible approach is warranted in this area.

Probably the most pressing problem in the design of protective pillars for underground structures is the design of pillars separating longwall panels. Economic considerations and operational aspects favour retreat longwall mining. To minimize the costs involved in the development, support, and maintenance of gate roads, and to effectively isolate longwall panels, it has become standard practice in South Africa to leave pillars between longwall panels. One of the main functions of these pillars is to protect the companion roadways from the effects of high abutment stresses at the edge of the longwall panels. The basic principles involved in the design of inter-panel pillars are shown in Fig. 13. The first step in the design procedure is to predict the stress distribution at the edge of the longwall panel. In the prediction of the abutment stresses, consideration has to be given to the composition of the roof strata and, in particular, the presence of competent beds. Once the stress distribution has been determined with the aid of finite-element or boundary-element stress-analysis techniques, the critical stress level, σ_{cr}, that can be tolerated by the roadway has to be determined. A first estimate of the magnitude of the critical stress level can be obtained from the average pillar stress in conventional bord-and-pillar sections in the same seam, which can be calculated according to the tributary-area theory:

$$\sigma_{cr} \approx p_m = \frac{\gamma H}{1-e}. \qquad (10)$$

Once the critical-stress level has been determined, the minimum pillar width can be read off the diagram. Because of the nature of the stress distribution at the edge of longwall panels, it is important to establish whether the critical-stress level falls in the steep or the flat portion of the stress profile. In the case of the former, it is advisable to increase the pillar width slightly to allow for any uncertainties arising from the often unknown extent of the fracture zone at the edge of the longwall panel.

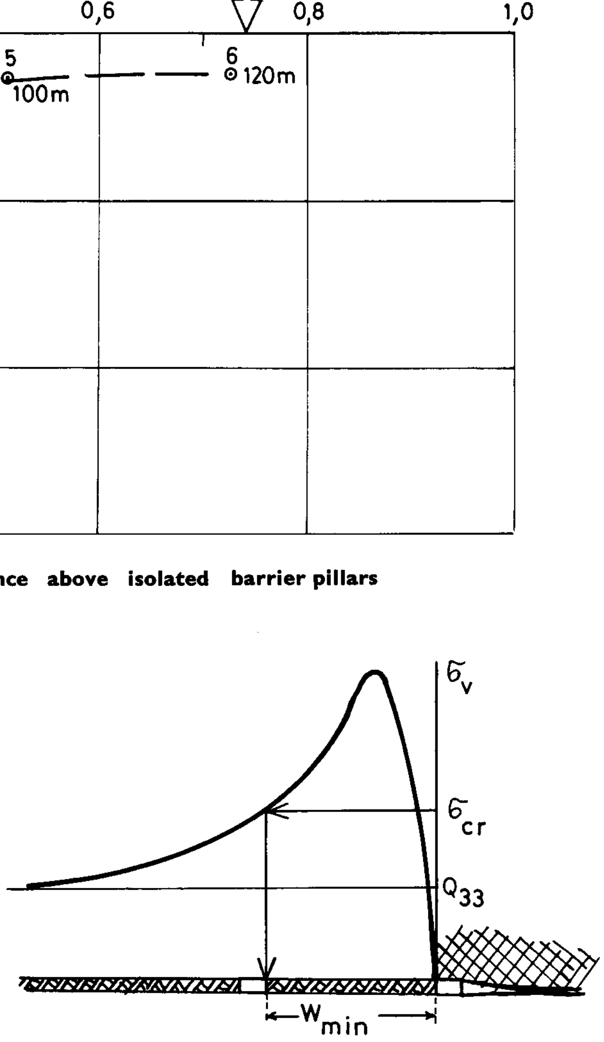

Fig. 13—Design procedure for inter-panel pillars

Conclusions

Since bord-and-pillar mining is to remain the most important method of coal extraction from underground for a long time to come, there is every incentive to refine the design procedures and so make more rational allowance for the differences in strength properties of the various coal seams and roof and floor strata. Any deviation from well-established design procedures must be based on sound engineering concepts and reliable data concerning the strength properties of the different coal seams.

The question of the protection of surface structures from the effects of underground coal extraction requires some rethinking in the light of the most recent information.

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Occupational risks

The Ninth World Congress on the Prevention of Occupational Accidents and Diseases will be held in Amsterdam from 6th to 9th May, 1980.

The theme of the Congress is 'Recent developments in the prevention of occupational risks within the enterprise', which is divided into the following three subthemes:

Organization of prevention within the enterprise
Research and exploitation of results
Equipment, methods, and workplace.

For further information write to Ninth World Congress on the Prevention of Occupational Accidents and Diseases, c/o Organisatie Bureau Amsterdam B.V., Europaplein 14, 1078 GZ Amsterdam, The Netherlands.

Explomet

An International Conference on the Metallurgical Effects of High Strain–Rate Deformation and Fabrication is to be held in Albuquerque, U.S.A., from 22nd to 26th June, 1980.

Explomet will provide a forum for the exchange of information on the metallurgical effects of explosive and other modes of high strain–rate deformation. The excellent response obtained from survey cards sent with the initial conference announcement indicates that the conference will be highly successful; colleagues from nine countries are currently planning to participate. The conference will consist of invited talks addressing broader areas and contributed talks reporting recent research efforts.

Further information is obtainable from Drs Marc A. Meyers and Lawrence E. Murr, Department of Metallurgical and Materials Engineering, New Mexico Tech, Socorro, New Mexico 87801, U.S.A.

Interkama 80

The 'International Congress with Exhibition for Instrumentation and Automation' (INTERKAMA) will be held from 9th to 15th October, 1980, in Düsseldorf.

The INTERKAMA, which is held every three years, still remains the largest fair of its kind in the world. It is supported, figuratively speaking, by four columns — the international exhibition, the scientific congress (which starts the day before the fair, i.e. on 8th October, 1980, and which is repeated during the course of the fair), the seminars given by the exhibiting firms, and the special exhibition, 'Applied Research', which facilitates the transfer of technology between research institutes and industry.

Further information is obtainable from Düsseldorfer Messegesellschaft mbH -NOWEA- Pressestelle INTERKAMA, Postfach 320203, D-4000 Düsseldorf 30, West Germany.