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A re-assessment of coal-pillar design*

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SYNOPSIS

The formula developed by Salamon and Munro in 1967 has been used for the past 22 years in the design of bord-and-pillar workings in South African collieries. This paper re-assesses the formula in the light of its past performance and examines the effect of mining method on coal-pillar strength. An account is given of the extension of the formula so that it can be applied beyond the empirical range for which it was derived, and the advantages of the extended formula (the squat-pillar formula) are described.

SAMEVATTING

Die formule wat Salamon en Munro in 1967 ontwikkel het, word die afgelope 22 jaar gebruik vir die ontwerp van pilaardelfplekke in Suid-Afrikaanse steenkoolmyne. Hierdie referaat gee 'n herwaardering van die formule in die lig van sy werkverrigting in die verlede en ondersoek die uitwerking van die mynboumetode op die sterkte van steenkoolpilare. Daar word verslag gedoen oor die uitbreiding van die formule sodat dit verder as die empiriese strek waarvoor dit afgelei is, toegepas kan word, en die voordele van die uitgebreide formule (die dikpilaarformule) word beskryf.

Introduction

The first report of a coal-pillar collapse in South Africa was in 1904 at the Witbank Colliery and, since that date, 81 pillar collapses have been recorded in 31 collieries in the Transvaal and Orange Free State. Between 1904 and 1965, there were 50 pillar collapses as reported by Salamon and Wilson[1].

In 1967, these collapses were examined by Salamon and Munro[2], who made a strict selection for statistical analysis. According to the criteria they adopted, only cases in which the information was sufficient and appeared to be reasonably reliable were included in the analysis; of these, the diameter of the pillar-collapse area had to be greater than the depth below surface, and the pillar geometry had to be regular. Excluded were cases in which bord collapse had obviously induced the pillar failure, those in which the final mining dimensions were unknown because of pillar robbing (or pillar 'slyping'), and those in which pillar collapse had occurred where two or more seams in close proximity to each other had been mined.

Salamon and Munro[2] used 27 of the 50 collapses recorded by Salamon and Wilson, and this major work gave rise to the safety-factor design formula currently used in the design of coal pillars in South African collieries.

The safety factor is defined[2] as

$$\text{Safety factor} = \frac{\text{Strength}}{\text{Load}}. \quad (1)$$

The calculation of load is based on the tributary-area or the modified cover-load theory. This can be applied provided the pillars are of a reasonably uniform geometry and that the panel width is greater than the depth below surface. Then, each individual pillar is assumed to carry the weight of the overburden immediately above it.

Thus load is calculated from

$$\text{Load} = \frac{25\,HC^2}{w^2}\ \text{kPa}, \quad (2)$$

where H is the depth of the floor of the seam, m
w is the pillar width, m
C is the pillar-centre distance, i.e. the sum of the pillar and bord width, m
25 is the multiples of the overburden density and gravitation.

The pillar strength formula is as follows:

$$\text{Strength} = kh^{\alpha}w^{\beta}, \quad (3)$$

where k is 7176 kPa, the strength of a unit cube of coal
α is −0,66
β is 0,46
w is the pillar width, m
h is the pillar height, m.

The values of 7,176, −0,66, and 0,46 were determined by Salamon and Munro[2] from their statistical analysis.

Performance of the Pillar-design Formula

Since the introduction of the pillar-design formula, 31 pillar collapses have been recorded (1966 to 1988). These were examined according to the same criteria as those used earlier, which resulted in the selection of the cases in which the pillars had failed because the load imposed upon them exceeded the strength of the pillars; 17 of the 31 cases satisfied the criteria. These collapses were then analysed together with the 27 earlier pillar collapses to show whether there were any new trends in the collapse of bord-and-pillar workings.

Table I shows the results, which indicate that there is little variation between the later and the earlier collapses.

The collapsed pillars that met the requirements for inclusion in the analysis are shown in Table II for individual coal seams. The largest group, 34 per cent of all collapsed pillars, occurred in the No. 2 Seam of the Witbank Coal-

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TABLE I

COMPARISON OF THE TWO ANALYSES OF COLLAPSED COAL PILLARS

Group	Unfailed	Collapsed 1904–1965	Collapsed 1966–1988
No. of cases in the group	98	27	17
Depth (H), m	20 – 220	21 – 192	22 – 205
Height (h), m	1,20 – 5,0	1,50 – 5,5	1,35 – 5,94
Pillar width (w), m	2,70 – 21,0	3,40 – 16,0	3,50 – 17,0
Extraction ratio, e	0,37 – 0,89	0,45 – 0,91	0,44 – 0,88
Width: height ratio (w/h)	1,20 – 8,8	0,90 – 3,6	1,30 – 3,7

field, which is the most extensively mined of all the coal seams in South Africa. The No. 4 Seam of the same coalfield, the second most-mined seam, had 18 per cent of the pillar collapses, and together the seams mined in the Witbank Coalfield made up 70 per cent of the collapses. All the major seams mined in the Transvaal and Orange Free State have experienced pillar collapses.

TABLE II

COLLAPSED PILLARS IN INDIVIDUAL SEAMS MEETING THE REQUIREMENTS FOR INCLUSION IN THE ANALYSIS[2]

	Intact cases 1965		Collapsed cases 1904–1965		Collapsed cases 1966–1988		All collapsed	
Seam	No.	%	No.	%	No.	%	No.	%
Witbank No. 5	7	7,5	3	11,1	2	11,8	5	11,4
Witbank No. 4	8	8,6	4	14,8	4	23,5	8	18,2
Witbank No. 2	45	48,8	9	33,3	6	35,3	15	34,1
Witbank No. 1	8	8,6	1	3,7	–	–	1	2,3
Springs	1	1,0	2	7,4	–	–	2	4,6
OFS No. 3	3	3,2	–	–	–	–	–	–
OFS No. 2	6	6,4	2	7,4	2	11,8	4	9,1
OFS No. 1	4	4,3	1	3,7	–	–	1	2,3
Main South Rand	1	1,0	3	11,1	3	17,7	6	13,6
Main OFS	3	3,2	1	2,7	–	–	1	2,3
Ermelo–Breyton C	6	6,4	1	2,7	–	–	1	2,3
	92		27		17		44	

The frequency of pillar collapse according to depth, pillar width, areal percentage extraction, and ratio of pillar width to mining height are plotted in Figs. 1 to 4.

Fig. 1 indicates that two-thirds of the collapsed pillars occurred at a depth of less than 70 m, with 34 per cent occurring below 40 m. Three of the later (1966 to 1988) cases, Nos. 148, 164, and 165, with safety factors of 1,52, 1,80, and 2,10 respectively, occurred at depths of 28,5 m, 33,0 m, and 22,0 m.

As shown in Fig. 2, 43 per cent of the collapsed pillars had widths of less than 6,0 m, while 29 per cent of the later collapses and 20 per cent of all the collapses occurred in pillars with a width of less than 4,0 m. The pillar widths in case Nos. 165 and 148 were 3,5 m and 3,8 m respectively.

Two-thirds of the collapsed pillars had an areal percentage extraction of more than 75 per cent (Fig. 3), and no pillar collapse was recorded where the width-to-height ratio was more than 4,0 (Fig. 4). Case Nos. 115 and 157 had the highest width-to-height ratios, being 3,58 and 3,74 respectively.

Safety factor versus frequency is illustrated in Fig. 5. As stated earlier, three later collapse cases, Nos. 148, 164, and 165, had safety factors greater than 1,46, which was the highest safety factor of the pillar collapses used in the analysis of Salamon and Munro[2].

Figs. 1 to 5 show that the 17 later pillar collapses conform to the trend of the 27 pillar collapses examined earlier. The later cases re-affirm the results of the earlier analysis, rather than showing a new trend.

Fig. 6 shows, for all the intact and collapsed pillars, the load acting on the pillar versus the calculated pillar strength, while the frequency distribution of the number of pillars involved in each collapse is illustrated in Fig. 7. Wherever possible, the actual number of pillars was obtained from mine plans. This applies to most of the later pillar collapses. The remainder were estimated. In three cases where the actual number of collapsed pillars was given, the estimated number of pillars was 70 to 100 per cent over the actual number quoted. Thus, the estimated number of pillars gives only an indication of the number of pillars involved.

The time between mining and pillar collapse versus safety factor, shown in Fig. 8, illustrates the considerable time taken for pillar collapse to occur. Of the 38 cases for which the time period was known, 26 per cent of the collapses occurred within the first year, and 50 per cent within 4 years of mining. Where an extension to the original pillar collapse occurred, the time period was taken from the date of mining to the date of the extension. This was done to conform to the method used by Salamon and Wilson[1].

Two significant features emerged from the analysis of the collapsed pillars.

(1) Pillars at depths of less than 40,0 m with widths of less than 4,0 m and a percentage extraction in excess of 75 per cent are prone to pillar collapse even when the designed safety factor is higher than 1,6. These three parameters are interrelated, and caution should be used in the designing of pillars at shallow depth. The effects of blast damage, geological discontinuities, weathering, or weak layers within the pillar influence the strength of small pillars more dramatically than they do larger pillars. Salamon and Oravecz[3], recognizing the dramatic effect of a small reduction in pillar width when the pillar is less than 4,5 m in width, suggested that no pillar should be mined with a width of less than 3,0 m and that pillars between 3,0 m and 4,5 m in width should have a safety factor of at least 1,7.

The present investigation suggests that, at depths of less than 40,0 m, pillar widths should preferably be greater than 5,0 m and the width-to-height ratio should be in excess of 2,0. In addition, a safety factor of more than 1,6 should be maintained.

(2) No collapse has been recorded for pillars with width-to-height ratios greater than 3,74. This suggests that the pillar-design formula under-estimates the strength of a pillar as its width-to-height ratio increases, as suggested by Salamon and Oravecz[3].

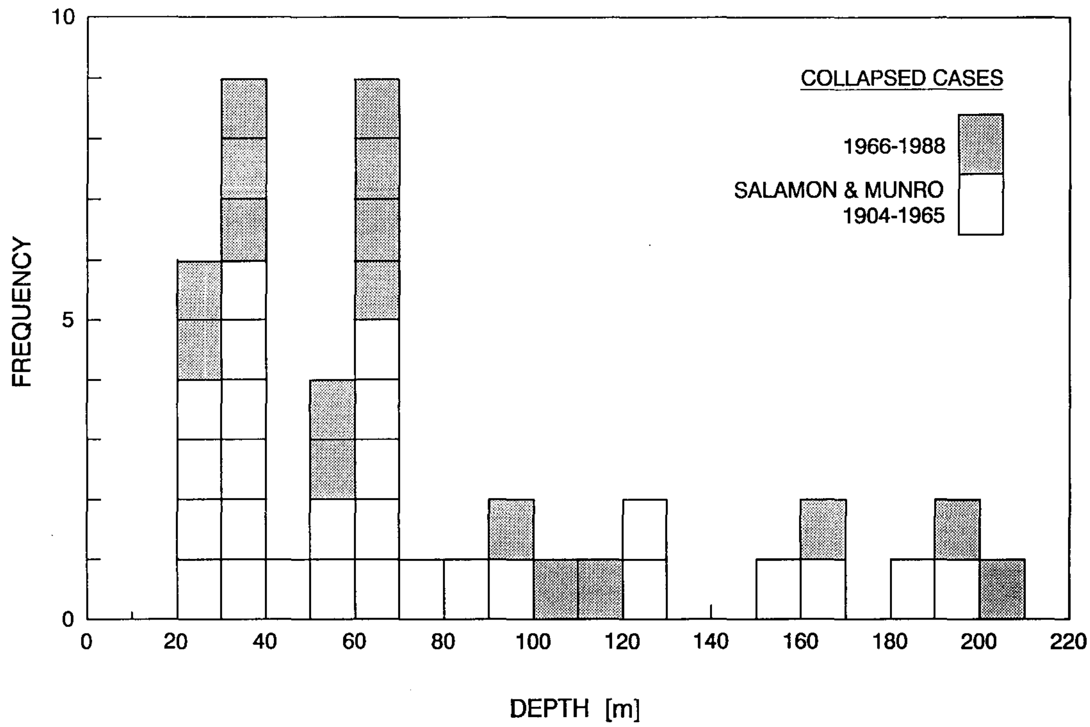

Fig. 1—Frequency of occurrence versus depth of intact and collapsed pillars

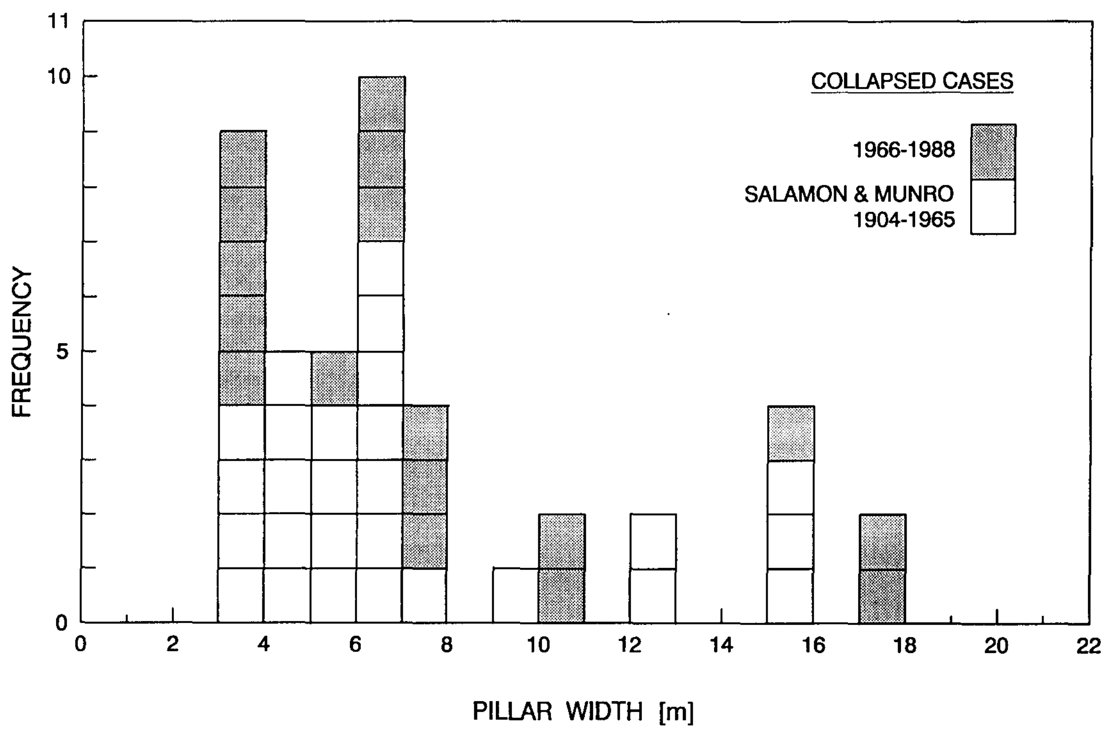

Fig. 2—Frequency of occurrence versus pillar width of intact and collapsed pillars

Using the same statistical technique as that used by Salamon and Munro[2], the 17 pillar collapses between 1966 and 1988 were analysed together with the original 27 collapsed pillars and 92 intact cases. This resulted in new k, α, and β parameters. However, when the strength calculated from both formulas was plotted (Fig. 9), there was little variation in strength over the empirical range covered by the formula. This confirms that the strength formula of Salamon and Munro[2] can successfully be used in the design of stable bord-and-pillar workings. When the data on individual seams were used, the statistical analysis showed that, although the strength of individual seams differs, there is no statistically significant difference between the strengths of individual seams so that the average strength could represent all seams. This result may be due to the anisotropic nature of coal and

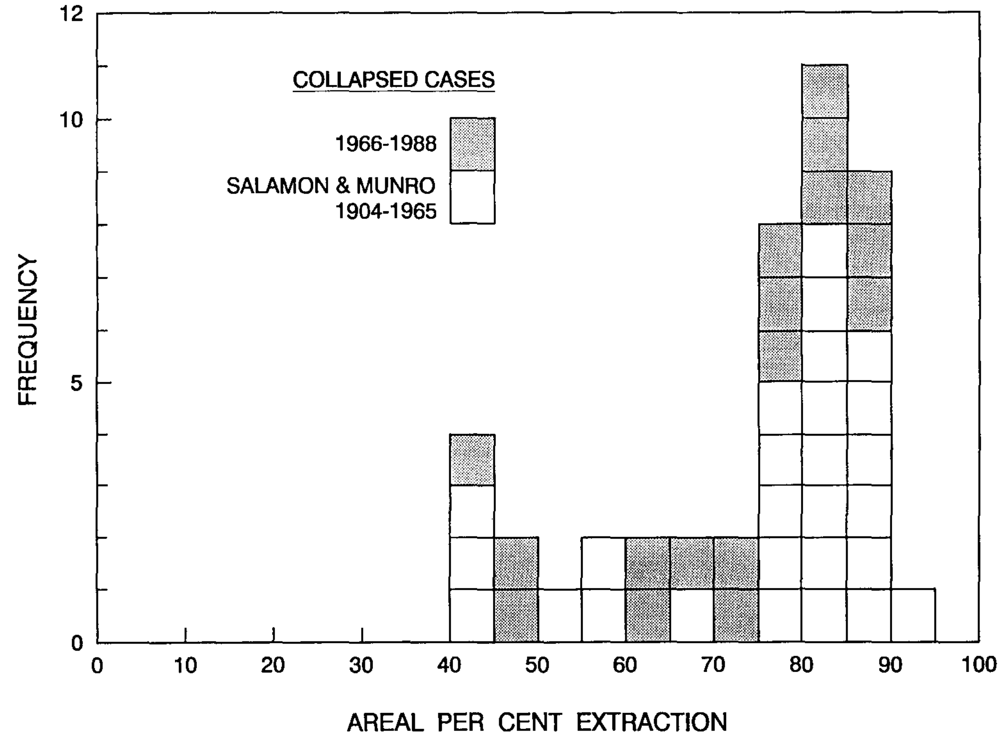

Fig. 3—Frequency of occurrence versus the areal percentage extraction of intact and collapsed pillars

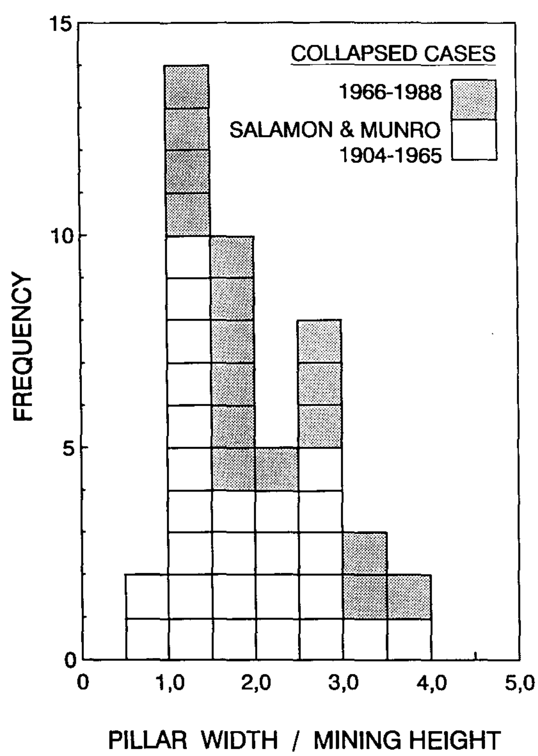

Fig. 4—Frequency of occurrence versus the pillar width-to-height ratio of intact and collapsed pillars

the influence of local variation in material properties, as well as to structural effects.

Effect of Mining Method on Pillar Strength

Blast vibration and the effect of gases from explosions as they penetrate existing discontinuities damage the skin of coal pillars formed by the conventional drill-and-blast technique. The fracturing thus caused reduces the strength of the perimeter of the pillar, resulting in a zone of weakness that is not present in pillars formed by continuous-miner techniques. This weakened zone spalls from the pillar side with time, and reduces the width of the pillar. Because the Salamon and Munro pillar-design formula is based on the designed mining dimensions of bord-and-pillar workings, all of which were mined by the drill-and-blast method, the formula for pillar strength indirectly takes into account the weakening effect of blast damage. Therefore, the effective width of a pillar designed according to the Salamon and Munro formula but mined by a continuous miner must be greater, by an amount approaching the extent of the blast zone, than that of a pillar formed by drilling and blasting (Fig. 10).

Around 80 per cent of all the coal produced in South Africa by underground mining methods is mined by the bord-and-pillar method. Continuous miners are responsible for approximately one quarter of this figure, which means that a large volume of coal may be left unnecessarily in coal pillars.

The depth of blast damage into the side of a pillar has been quantified[4] as being between 0,25 and 0,3 m. The effect on the safety factor of a pillar formed by a continuous miner can be estimated on the assumption that the effective pillar width increases by the depth of the fractured zone that would be present in a pillar mined by the conventional methods. If the nominal pillar width, w, results in a safety factor η, then the safety factor of bord-and-pillar workings developed by means of a continuous miner, η_o, can be calculated from the following expression after Wagner and Madden[5]:

$$\eta_o = \eta\left(1 + \frac{2\Delta w_o}{w}\right)^{2,46} \quad \text{.............................. (4)}$$

This expression calculates the increased safety factor of

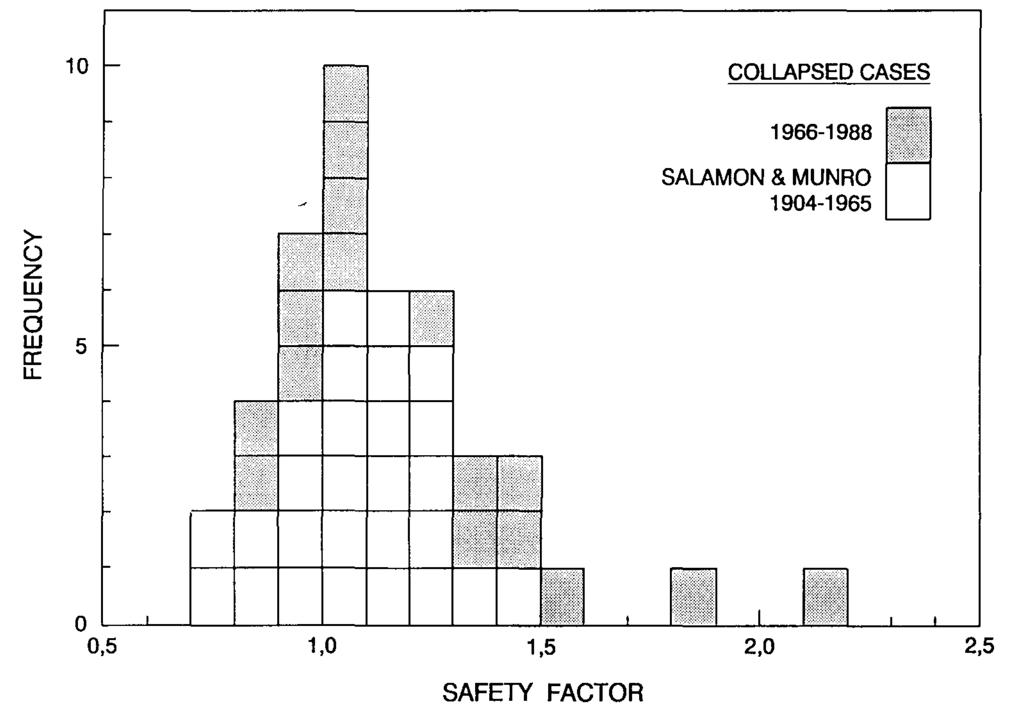

Fig. 5—Frequency of occurrence versus the designed safety factor for intact and collapsed pillars

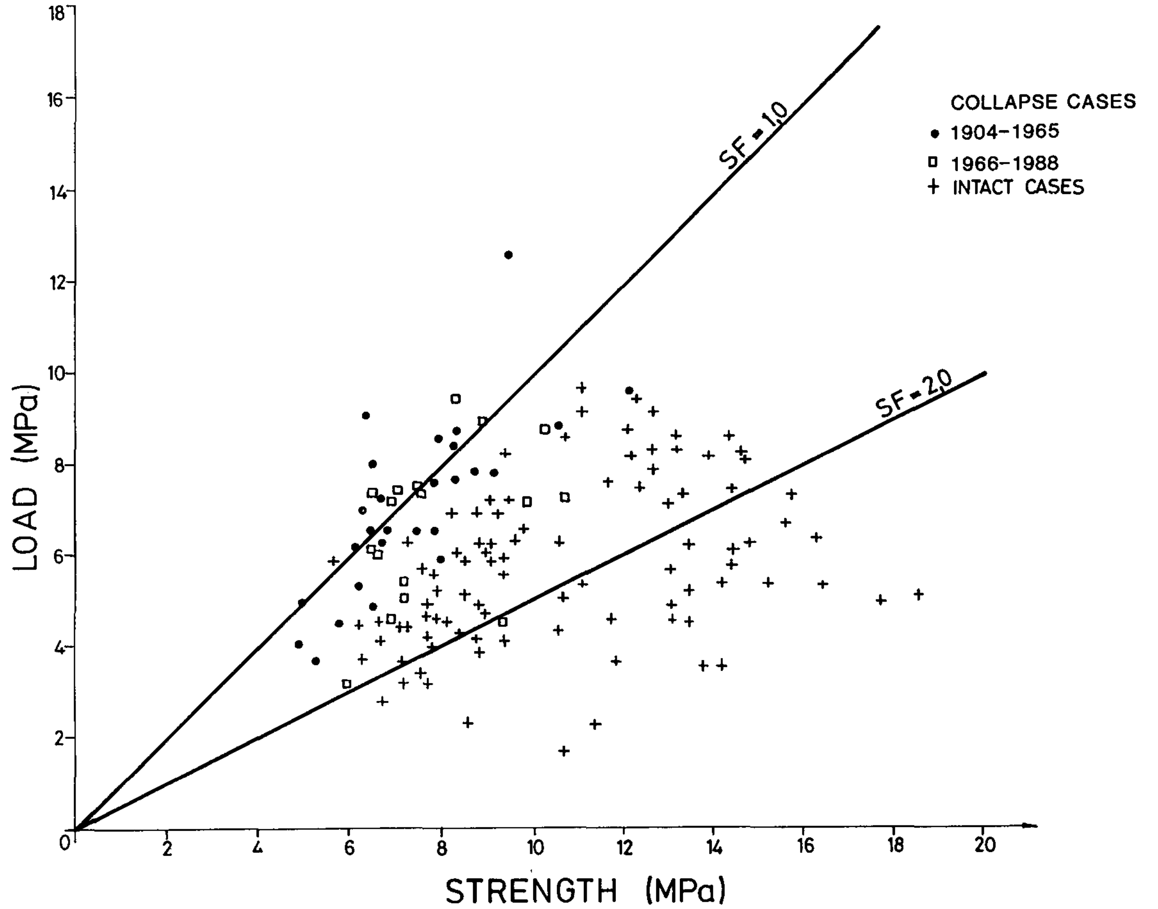

Fig. 6—Load versus strength of intact and collapsed pillars

a continuous miner in that the absence of a blast-damage zone gives the pillar additional strength.

Thus, if the pillar width, *w*, were 10 m, the designed safety factor 1,6, and the blast-damage zone 0,3 m, the safety factor of a pillar formed by a continuous miner would be 1,85.

Alternatively, the pillar width could be reduced by the extent of the blast-damage zone. However, this necessitates increasing the bord width by the corresponding amount. By this method, the strength of the smaller pillar

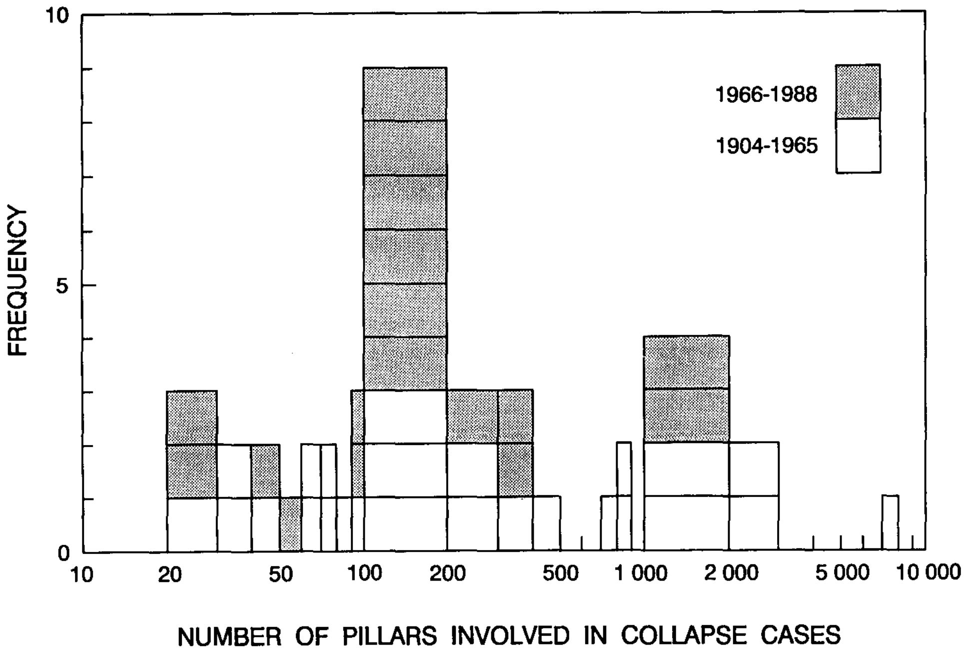

Fig. 7—Frequency of occurrence versus the estimated number of pillar collapses

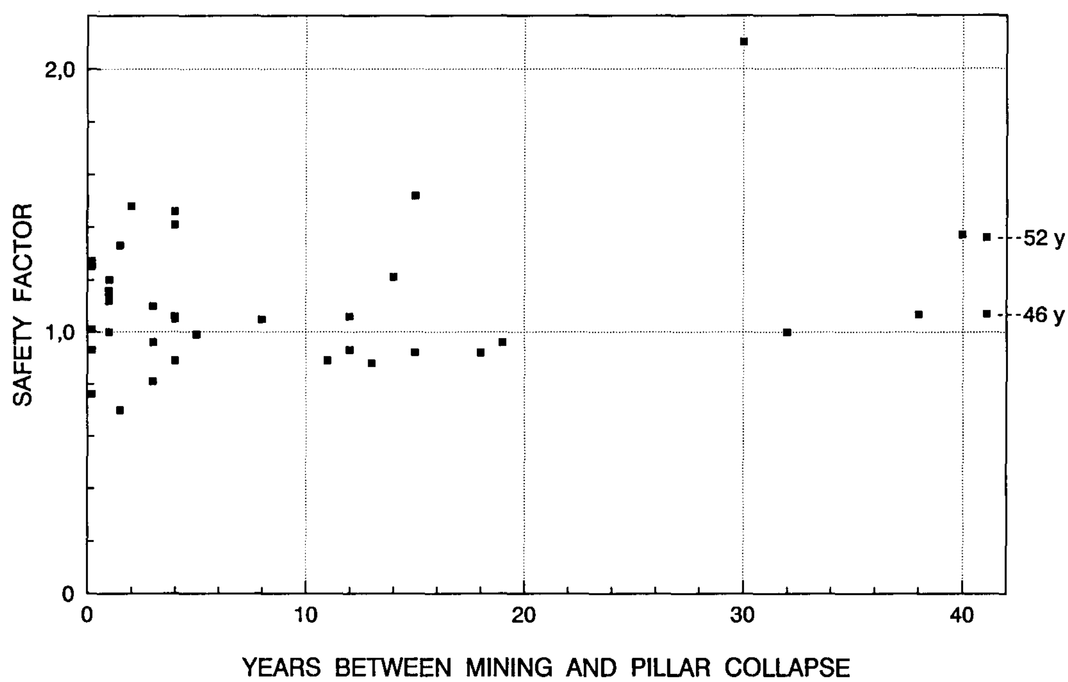

Fig. 8—Safety factor versus the time period between the mining and collapse of coal pillars

formed by a continuous miner is of *equivalent* strength to the larger conventionally formed pillar, even though the safety factor for the former as calculated is less than that recommended by Salamon and Munro[2].

Two important points should be noted.

(a) For a pillar formed by a continuous miner, there is a fixed reduction in pillar width by the extent of the blast-damage zone, and not a fixed reduction in safety factor.

(b) It is the strength calculation of the pillar formed by a continuous miner that is being adjusted by this method, not the safety-factor design formula.

The benefits in terms of increased extraction from pillars formed by a continuous miner are given in Fig. 11, which shows that the increase in extraction can be between 3 and 4,75 per cent.

In 1988, 23 Mt of coal was produced in bord-and-pillar workings by continuous miners. Using the method described, which allows for the increased strength of a pillar formed by a continuous miner, this equates to a potential annual saving of between 250 and 350 kt of coal that would otherwise be locked up unnecessarily in permanent support pillars.

The use of continuous miners permits the designed

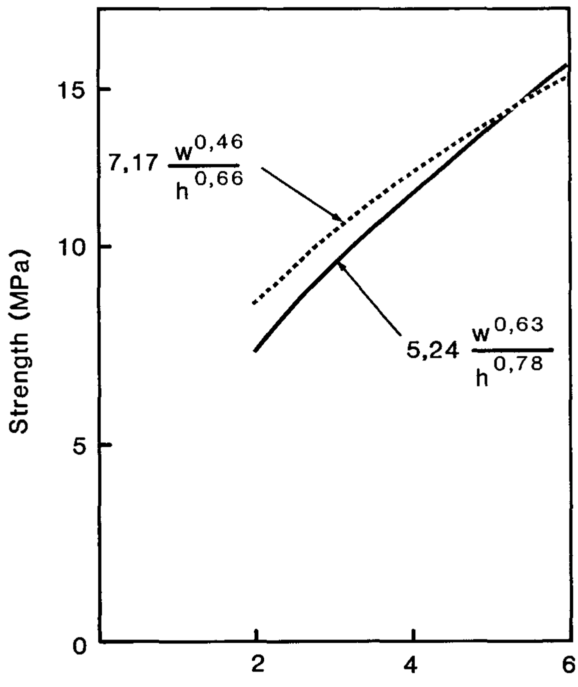

Fig. 9—Strength versus width-to-height ratio from the formula of Salamon and Munro[2] and that derived from additional data

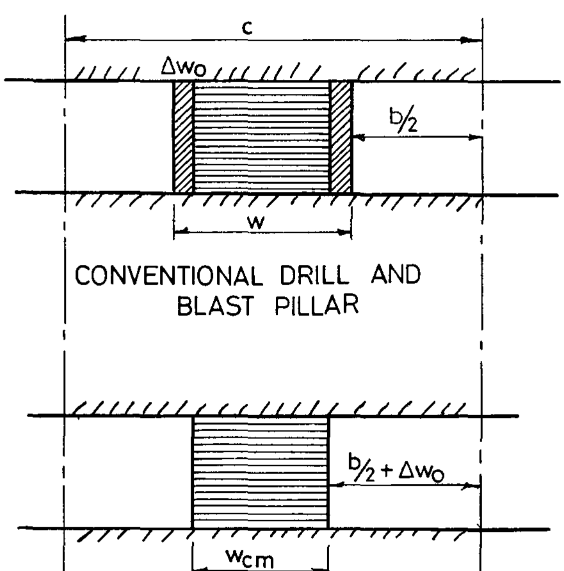

Fig. 10—Pillar formed by a continuous miner that is of equivalent strength to that of the conventional pillar shown

C = Pillar-centre distance
Δ_{wo} = Blast-damage zone
b = Bord width
w = Pillar width
w_{cm} = Equivalent width of a pillar formed by a continuous miner: $w - 2\Delta_{wo}$

pillar width to be reduced by the extent of the blast-damage zone, and this has the greatest benefit in terms of increased extraction where the reduction in pillar width does not result in an excessive concentration of stress over the pillar's edge.

Maximum benefit in terms of increased extraction from the use of continuous miners occurs between pillars greater in width than 5,0 m and at depths of less than 175 m. This is due to the fact that stress-induced sidewall slabbing can occur in very small pillars and at depths of more than 175 m.

The Squat-pillar Design Method

The safety-factor design formula of Salamon and Munro[2] has been used very successfully in the design of pillars with stable geometries in South African collieries. This formula was developed for collieries in which the depth of mining ranges between 20 and 220 m. In the past, most collieries in South Africa operated at depths of less than 150 m, and the problem of squat coal pillars never arose.

The pillar-strength formula (3) assumes that the strength of a pillar increases proportionally with a power of the width-to-height ratio that is less than unity. This limitation was not evident in the statistical study by Salamon and Munro[2] because the collapsed pillars examined included only pillars with width-to-height ratios of 3,6 or less. However, the coal being mined in most of the newer collieries, and in some of the reserves currently being mined on older collieries, are situated at depths in excess of 150 m and up to 580 m. Because these cases extend beyond the empirical range of Salamon and Munro's statistical analysis, Salamon[5] in 1982 extended the pillar-strength formula (3) to take cognizance of the increasing ability of a pillar to carry load with increasing width-to-height ratio.

Laboratory tests on sandstone specimens were analysed by Wagner and Madden[6] to examine the suitability of the new formula, known as the squat-pillar formula, to predict the strength increase with increasing width-to-height ratios. The squat-pillar formula was found to fit the laboratory results well and, although these laboratory results cannot be related directly to coal pillars because of the difference in the material, scale, and time taken to test the samples, the general trend can be assumed to be similar.

The strength of a pillar given by the squat-pillar formula is

$$\sigma_s = k\,\frac{R_o^b}{V^a}\left\{\frac{b}{\epsilon}\left[\left(\frac{R}{R_o}\right)^{\epsilon} - 1\right] + 1\right\}, \quad \ldots\ldots\ldots\ldots\ldots\ (5)$$

where R_o is the critical width-to-height ratio
ϵ is the rate of strength increase
a is 0,0667
b is 0,5933.

Salamon and Wagner[7] suggested that the squat-pillar formula could be used with the critical width-to-height ratio (R_o) taken as 5,0 and that ϵ could be taken as 2,5, although a realistic estimate was more difficult for the latter. The assumption of 5 for R_o is based on the fact that no pillar with a width-to-height ratio of more than 3,75 is known to have collapsed.

Field investigations into the performance of squat pillars were conducted at Longridge and Piet Retief Collieries, where the extent of pillar sidewall fracturing was recorded by use of a petroscope with a surveyor's dumpy level. The observation holes were drilled 6,0 m into the pillar sides with an electric face drill having bits of 38 mm

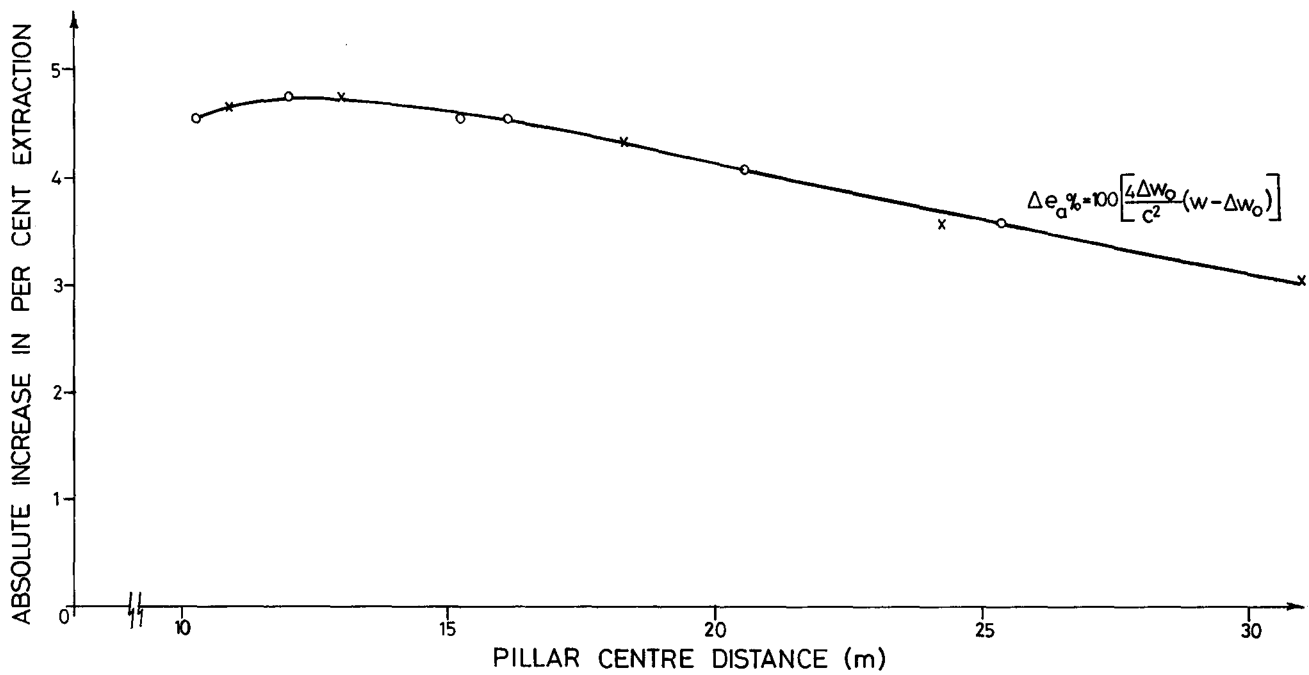

Fig. 11—Absolute increase in percentage extraction for a pillar formed by a continuous miner over that for a pillar formed by drill-and-blast extraction

diameter. This hole was then reamed with a 50 mm bit to allow the petroscope to negotiate deviations due to drilling. The holes were flushed with air or water to remove the fine duff and expose the cracks in the borehole.

Fractures could be seen in the hole without the aid of a dumpy level up to a distance of 2,0 m. Beyond that distance, the dumpy level was required. It is estimated that fractures greater than about 1 mm wide could be observed but, for fractures less than 1 mm wide, it is thought that the flushing had covered the fracture with the fine coal resulting from drilling. Although the maximum length of hole drilled was 14,0 m, borehole deviation caused a loss of petroscope sighting after about 8,0 m.

In the investigations, a minimum of twenty holes were drilled at each site so that the fracture frequencies could be calculated. The maximum extent of fracturing, as well as the typical fracture pattern, observed at Longridge and Piet Refief Collieries under a range of depths and safety factors is shown in Fig. 12. Intense fracturing, with fractures up to 50 mm wide, occurred in the first 0,3 to 0,5 m of the pillar side. This was generally followed by solid coal for about 0,5 to 1,0 m, with one or several smaller fractures (about 2,0 to 5,0 mm).

At Longridge Colliery, this pattern extended to a maximum of 2,6 m in pillars with a width-to-height ratio of 6,22 at a depth of 155 m. At a depth of 252 m at the same colliery and a width-to-height ratio of 12,8, fracturing extended for only 1,5 m into the pillar side. The safety factors according to the Salamon and Munro formula at the two depths were 1,86 and 2,18 respectively, and, according to the squat-pillar formula, they were 1,92 and 4,07. The fracture observations at Longridge Colliery were in pillars mined at least three years previously.

At Piet Retief Colliery, the maximum fracture depth observed was 1,9 m into the pillar side. The pillar width was 28,0 m, the width-to-height ratio 14,0, the depth 550 m, and the safety factors 1,04 and 2,19 according to the Salamon and Munro and squat-pillar design formulas respectively. The stress in the centre of pillars designed according to the squat-pillar formula had returned to near-virgin conditions.

These results showed that fracturing occurs only in the outer skin of pillars with high width-to-height ratios, even when the sides are subjected to stress in excess of the accepted strength of coal. It also shows that the Salamon and Munro design method, when extended to the design of pillars at 550 m depth, is extremely conservative in view of the large proportion of pillar that remains intact.

Extensive field trials at Hlobane and Piet Refief Collieries showed that the squat-pillar formula gives stable pillar dimensions. The pillar sizes are substantially smaller than pillars designed according to the earlier method, and the extent of fracturing is confined to the perimeter of the pillar. For a safety factor of 2,0, a large portion of the pillar remains intact.

Measurements of pillar dilation in a stooping section at Hlobane Colliery showed that pillars with high width-to-height ratios were stable during their extraction, while increasing overburden load was being carried.

It was not possible to determine an alternative value for parameter ϵ since it is sensitive to small changes in pillar width. The stress in the centre of the pillars at Piet Retief Colliery was close to virgin stress, indicating that the assumed value of 2,5 for ϵ is a conservative estimate but results in a substantially improved design method. Fig. 13 is a plot of the squat-pillar and Salamon and Munro's formulas for various width-to-height ratios, and shows the rapid increase in strength of a squat pillar at high width-to-height ratios.

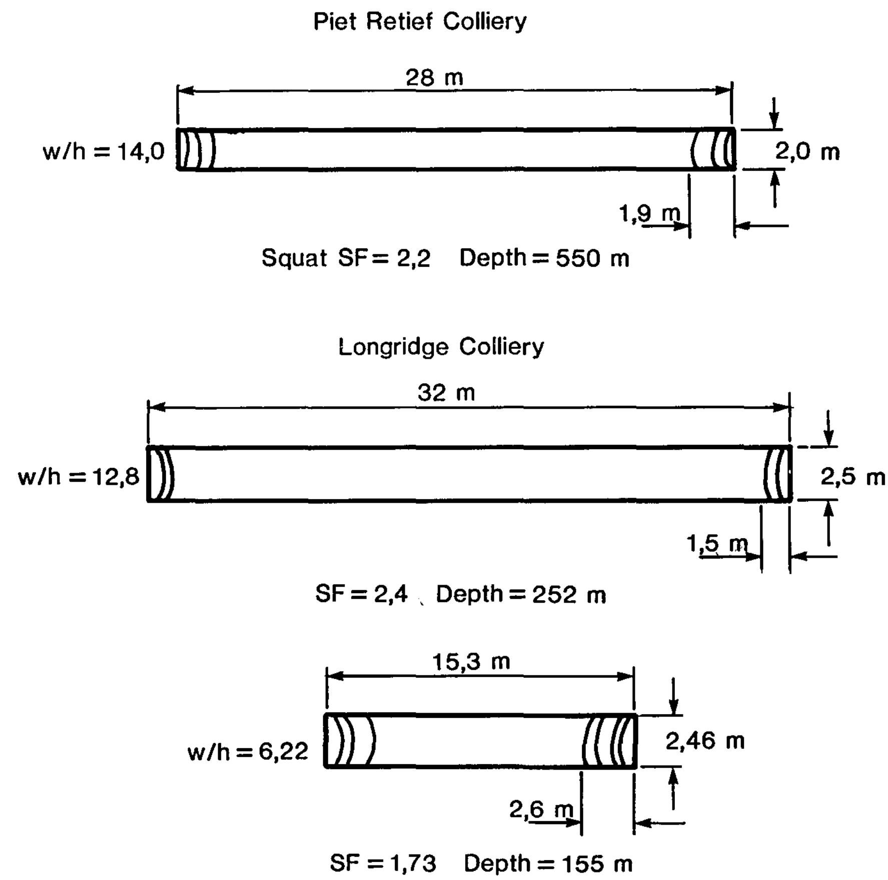

Fig. 12—Extent of fractures observed in pillars

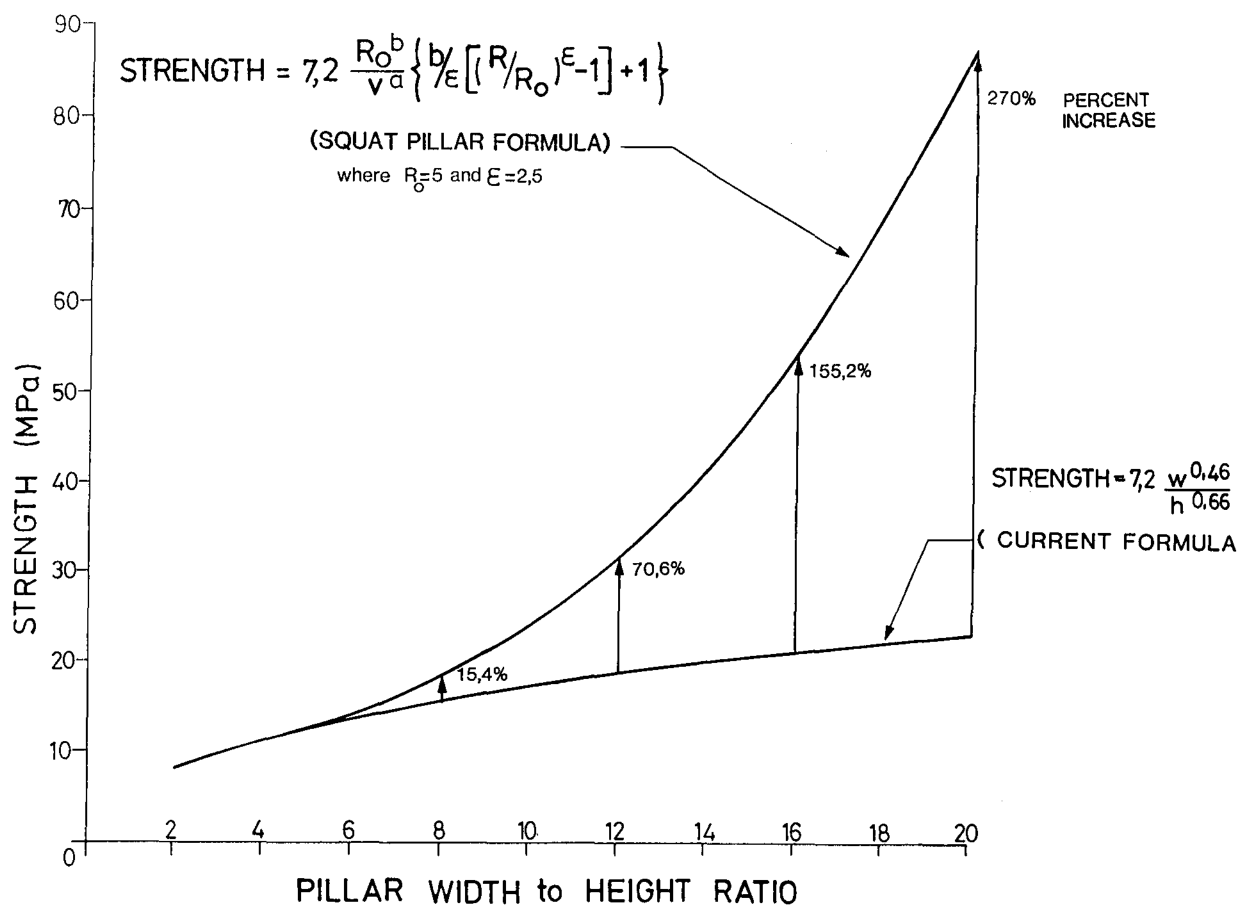

Fig. 13—Pillar strength calculated according to the squat-pillar formula and that calculated according to the Salamon and Munro pillar-strength equation

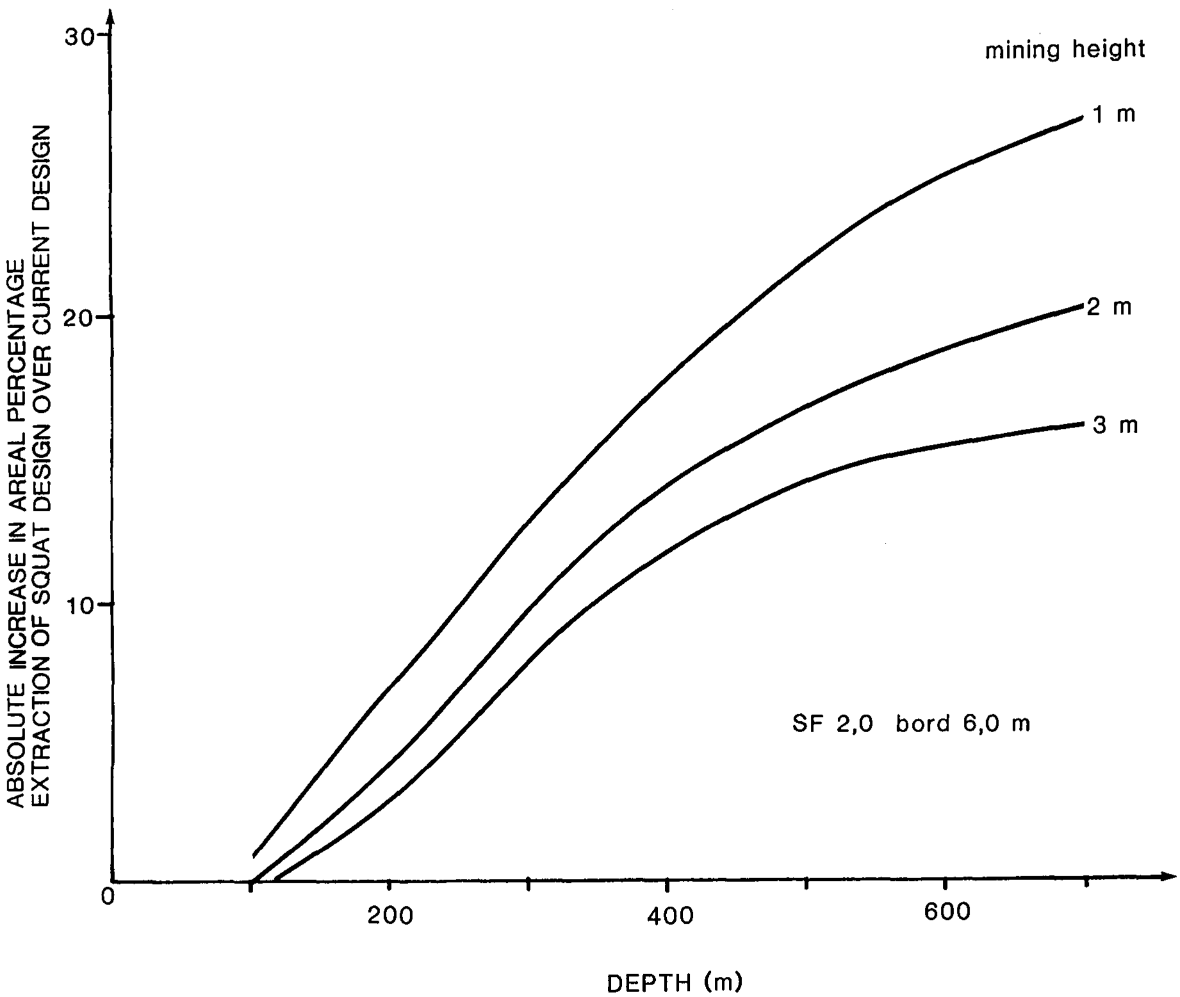

Fig. 14—Benefit in areal percentage extraction of the squat-design pillar over that of the Salamon and Munro design for various depths

Benefits of the Squat-pillar Formula[8]

Permanent support pillars have to be left under surface restrictions such as buildings, railway lines, canals, and roads. The design of main developments and shaft bottoms requires pillars to remain stable for the life of a mine, which may exceed 50 years. In these cases, a design safety factor in excess of 2,0 is used.

The benefit of the squat-pillar formula, in terms of increased extraction of coal, can be seen by the absolute increase in areal percentage extraction over that provided by the Salamon and Munro formula (Fig. 14). The oversupply of coal on the world market and the rising costs of labour and stores have made it essential that the working costs of the coal mined should be kept to a minimum. One way of reducing the cost of coal per ton mined is to increase productivity.

To determine the increase in productivity from the use of the squat-pillar formula, a computer simulation of production from sections designed to both formulas was investigated using the program COMSIN, which was developed by the Chamber of Mines Research Organization (COMRO). The pillar geometries were calculated by use of the Salamon and Munro and squat-pillar formulas for mining heights of 1, 2, and 3 m at depths of between 200 and 500 m, a safety factor of 2,0, and a bord width of 6,0 m. Fig. 15 shows the percentage increase in productivity, as well as the percentage decrease in tramming distance for a shuttle car, and indicates the tremendous benefits resulting from the application of the squat-pillar formula. In addition, benefits in improved ventilation and increased utilization of shuttle cars result from the reduced pillar-centre distances.

Conclusions

The re-assessment of the design of pillars for South African collieries showed that the formula of Salamon and Munro[2] is very successful in the designing of stable bord-and-pillar geometries within its empirical range. Caution should be exercised in the design of pillars at depths of less than 40 m since pillars with width-to-height ratios of less than 1,75, an areal extraction of more than 75 per cent, and a width of less than 6,0 m are prone to collapse despite safety factors in excess of 1,6.

When allowance is made for the absence of a blast-damage zone in pillars formed by a continuous miner, the pillar width can be less by the extent of the blast damage while still having the equivalent strength of the larger, conventionally formed pillar. This results, at current production rates, in an increase of between 250 and 350 kt annually in extractable coal reserves.

The reduced pillar sizes resulting from the application of the squat-pillar formula lead to an increase in percentage extraction and an increase in productivity. In addi-

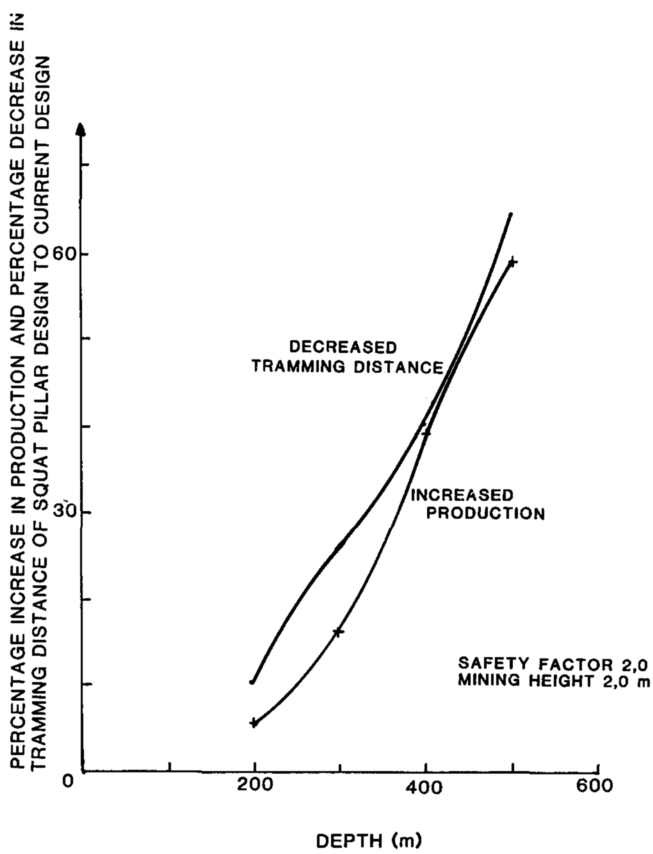

Fig. 15—Percentage increase in production and percentage decrease in tramming distance of the squat-pillar design over that of the Salamon and Munro design for various depths

tion, benefits will be gained from better ventilation and utilization of equipment. Overall working costs will be lower, and the safety of men and equipment will remain secure.

The extension of the design formula of Salamon and Munro[2] to the squat-pillar formula has provided a realistic design method that can be applied with confidence.

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Engineering NDT

Advances in South African fabrication and construction industries have necessitated higher non-destructive testing (NDT) technology to ensure integrity and fitness for purpose. It has been found that there is little awareness about advanced NDT in the RSA at present. Also, current exchange rates have made many South African industrial products competitive in world markets. Even Japan and Europe have become accessible. In many instances, these vast potential markets are not exploited because of poor or inappropriate NDT of the final product.

An urgent need has consequently been recognized for university graduates and others involved to undertake an intensive high-level course in NDT methods. Cost-effective application of NDT requires the design of particular components to be adapted so that these techniques can be executed rapidly and reliably. This, in turn, requires full managerial commitment to NDT and, hence, a total quality approach from initial concept through to final product.

The University of Pretoria, in collaboration with the South African Institute for Non-Destructive Testing (SAINT), will be presenting a 5-day summer school at academic level to promote NDT as a science equivalent to other sciences. Special guest lecturer Prof. Dr-Ing D.H. Stegemann, Head of the Institute for Nuclear Engineering and Non-destructive Testing of Hannover University, has been invited to present most of the lectures.

The course has been designed for all engineers, managers, designers, and practising NDT technologists who recognize that the development of their companies is dependent on the utilization of advanced NDT technology.

The NDT Summer School is to be held in Pretoria from 30th September to 4th October, 1991.

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