ELEMENTARY ENGINEERING SCIENCE - A MEANS TO CHANGE SAFETY CULTURE IN COAL MINING

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INTRODUCTION

Safety may be defined as "a state of mind by which persons are constantly made aware of the possibility of injury at all times". (George, 1942). In other words, safety is an attitude and, therefore, changing the safety culture is about changing attitudes.

Simply possessing a positive attitude to safety, however, does not guarantee an acceptable safety performance. The most safety conscious workforce will not achieve a safe working record if the systems they have to work with are not properly engineered. Engineering formed the basis of the three E's for safety proposed by George (1942):

- Engineering
- Education
- Enforcement (make clear and understandable).

The principles find universal application. This paper draws on research outputs from the Strata Control for Coal Mine Design Project at the University of New South Wales to illustrate the principles in action, especially that of the foundation stone - Engineering Science. An improved understanding of engineering science principles is an effective means to change safety culture and enhance safety performance.

THE ROLE OF ENGINEERING SCIENCE

The World Book Dictionary defines engineering as "the application of knowledge of mathematical and physical sciences acquired through education, training and experience to the planning, design and supervision of systems". Thus, engineering science principles (mathematics and physics) underpin the effective execution of the functions of management to:

- Anticipate
- Plan
- Implement
- Control
- Monitor
- Take effective remedial action.

Some, or all of these functions, have to be exercised to various degrees by all members of the workforce. In pillar extraction for example, the mine manager has to execute all functions in devising a safe system of extracting pillars. Having been given the system, there is a responsibility on the face supervisor to be constantly controlling and monitoring performance and to have an input into effective remedial action.

A knowledge of fundamental engineering science principles plays two critical roles in improving safety performance:

1. It enables the mechanisms of behaviour to be identified, thus removing the guess work and trial and error out of the solution process, and it gives confidence to the application of the solution to other environments. An understanding of the mechanics of the problem provides a disciplined approach to investigations, data collection and analysis, design, risk management, and the implementation of effective remedial actions. Conversely, a lack of such understanding can lead to a variety of interpretations of events and causes being assigned to a mishap. Some interpretations may be correct and effective in preventing a recurrence. Others can be wrong and, thereby, aggravate the problem.

2. Knowledge motivates learning and changing attitudes. "Do's" and "Don't's" are just rules to the uninformed which should be obeyed and which, hopefully, cover all situations. A knowledge of engineering science principles, even if very basic, offers an explanation to the Do's and Don't's, motivates compliance and gives direction to dealing safely with new or unexpected situations.

STRATA CONTROL FOR COAL MINE DESIGN PROJECT

Research being conducted by the Strata Control for Coal Mine Design (SCCMD) Project Team at the University of New South Wales provides a number of examples of how safety culture can be changed and safety performance improved through the application of fundamental engineering science principles. The SCCMD Project is being funded by the New South Wales Joint Coal Board over a four year period. The Joint Coal Board is the coal industry's insurers in New South Wales. The Project was instigated in 1992 following a number of mishaps in bord and pillar and pillar extraction workings.

In the preceding decade, falls of roof and ribs caused the deaths of 30 miners in New South Wales. There has been at least 8 sudden and extensive collapses of pillar workings. In the same period, 15 fatalities occurred during pillar extraction. Of these, 12 were associated with events where continuous miners were buried. There were 60 incidents where continuous miners were buried for periods exceeding 7 hours in the three year period to 1992. Clearly, these occurrences represent unacceptable risks on the safety triangle.

An analytical review of the mishaps has highlighted the need to advance the theoretical knowledge of pillar mechanics to improve safety. This involves the application of mechanical engineering principles to the geological environment. Reviews of field performances enable operating mines to be used as the testing laboratory. Soundly engineered outcomes are equally relevant to roadway performance, rib stability, longwall mining and metalliferous mining.

Knowledge transfer is being effected through the publication of a four monthly newsletter distributed throughout the Australasian coal industry, face to face technology transfer workshops, seminars and written reports. Examples taken from the Project's research and technology transfer initiatives illustrate the important role of fundamental engineering science in changing the safety culture and improving safety performance.

COAL PILLAR DESIGN

In competent roof and floor environments, coal pillar failure occurs when the load acting on the coal pillar exceeds the strength of the coal pillar. The term 'Safety Factor' describes this relationship.

Ideally, a Safety Factor greater than 1, say 1.01, means that a structure is stronger than the greatest load to which it will be subjected. Therefore, the structure will be stable. Conversely, a Safety Factor of less than 1, say 0.99, means that the load applied to the structure will exceed its strength and the structure will fail. A Safety Factor value of 1, therefore, implies only a 50% probability of stability. In other words, there is an even chance of the system failing or being stable.

In structural engineering, the precise values of the strength, the load and the material properties are not usually known. The probability of human error in the execution of the design, unplanned events and the consequences of failure also need to be considered. The engineer caters for those issues by increasing the safety factor if the confidence in the design is low or the consequences of failure are serious.

A fundamental principle that needs to be recognised in the industry is that:

A safety factor is not an absolute measure of safety but rather a measure of probability that a design will be stable.

When pillar load exceeds strength and pillar failure occurs, it takes one of two forms:

- Gradual, in which case, there is ample warning over time in the form of pillar spall and rib crush. Such collapses are said to be controlled and can often be arrested through the installation of additional support.
- Sudden, whereby failure is not necessarily preceded by deterioration of the pillars. Once failure has been initiated, it can develop rapidly and cannot be arrested. Such collapses are referred to as uncontrolled.

Operators need to appreciate that the mechanics of sudden collapses are such that no warning signs of impending failure may be apparent. The best known example of a sudden collapse is that of Coalbrook Colliery in South Africa in which 4,400 coal pillars failed in a 20 minute period in 1960, killing all 437 men underground. Similar collapses have been documented in metal mines, e.g. Lorraine Iron Ore Mine in France.

In the decade following the Coalbrook Collapse, extensive research was undertaken into pillar mechanics. It was established that the ratio between the stiffness of the coal pillars and the stiffness of the surrounding roof and floor strata determines whether, if pillar failure should occur, the collapse will be gradual and controlled or sudden and uncontrolled. The stiffness of the coal pillars is governed by the pillar w/h ratio. The stiffness of the surrounding strata is governed by the ratio of overall panel width, W, to depth, H, i.e., W/H, and by the elastic modulus, E, of the strata.

The research lead to the formulation in South Africa of two coal pillar strength formula, namely:

Max σ_p = pillar strength (MPa)
w = pillar width (m)
h = pillar height (m)
7.2, 6.2 = measures of coal strength

Both formulae recognise the long known over-riding effect of pillar width to height ratio, w/h, on pillar strength. Salamon and Munro's formula was derived on the basis of the field performance of over 50,000 pillars and has been the standard design procedure for the South African industry since the early 1970's. In the 1980's it was extended (Equation 4) to cover pillars having a w/h ratio greater than 5 (which fell outside the range of the original data).

Based on the extensive field performance data, Salamon and Munro were able to assign a probability of stability to coal pillar safety factors, Figure 1. These probabilities formed the basis for Salamon and Oravecz (1975) recommending the following safety factors for stability.

Typical Bord and Pillar Workings	1.6
Geologically Disturbed Areas	1.7
Superimposed Multi-Seam Workings	1.7
Main Developments	2.0
Undermining of Important Surface Structures	2.0
Extremely Competent Coal Seams	1.5

Bieniawski applied his formula to USA conditions in the late 1970's. Based on local field experience, he recommended a safety factor of 1.5 to 2.0 to ensure long-term stability when using his formula under USA conditions. A comparison between the two formulae is shown in Figure 2. It is noteworthy that at a typical mining height of 3 m, a Salamon Safety Factor of 1.6 corresponds almost exactly to a Bieniawski Safety Factor of 2.0 down to a depth of 300m.

The effect of mining height on pillar strength was qualitatively recognised over a century ago and quantifiable by the late 1970's. Nevertheless, when a new Coal Mines Regulation Act (CMRA) was introduced into New South Wales in 1982, it not only failed to recognise the effect of mining height on pillar strength, but also removed a blanket limitation on mining height which existed in the previous CMRA. The CMRA (1982) stipulated a minimum pillar width of one tenth depth or 10m, whichever is the greater.

There have been at least four extensive collapses of bord and pillar workings in New South Wales designed since 1982 in compliance with the CMRA (1982). All were sudden, uncontrolled collapses. A number of sudden, uncontrolled collapses have also occurred in Queensland during this period. Five collapses have occurred in active working sections. On only one occasion were warning signs apparent and workmen withdrawn. Fortunately, the remaining four collapses occurred on non-working days or when sections were idle because of breakdown. On the one occasion that the workforce were withdrawn, they had been working in a section where over 200 pillars had failed suddenly a number of weeks earlier whilst the continuous miner was away for repairs. Clearly, good luck was still involved in this situation since, if there had been an awareness of sudden, uncontrolled collapse mechanisms, work would not have been permitted to resume in the section following the first collapse.

Table 1 records both the Salamon and Munro and the Bieniawski Safety Factors associated with collapses investigated by the SCCMD Project of Australian bord and pillar workings in competent roof and floor conditions. In all cases, the safety factor of the collapsed Australian cases is less than that recommended by the respective authors to ensure long-term stability. The necessity for the New South Wales Chief Inspector of Coal Mines to subsequently place restrictions on mining heights in excess of 4m is obvious.

It is also significant that all collapses were associated with small pillar w/h ratios and shallow but extensive workings giving large W/H ratios. The application of engineering science principles established nearly two decades ago leads to the obvious conclusions that the probability of collapse was high (over 75% in one case) and that such collapses would give little, if any, warning and 'run' once initiated.

One operation was deliberately designed to a Salamon and Munro Safety Factor of 1.2, based on nominal dimensions. The operators were obviously unaware that even if actual dimensions were to design, there was a 13% probability of collapse and that this would be sudden. Such probabilities and consequences are unacceptable to today's safety targets and attitudes.

The SCCMD Project is extending formulae of the type of Bieniawski and Salamon and Munro to Australian conditions. The Project has also significantly advanced the theoretical understanding of post failure deformation behaviour of coal pillars. These advances are essential to performing safely and effectively, the management functions of Anticipation, Design and Effective Remedial Action, especially in the areas of total extraction mining systems and regional mine stability.

BURIED CONTINUOUS MINERS

The SCCMD has undertaken an analytical review of investigation reports relating to 60 incidents where continuous miners were buried for more than 7 hours in New South Wales in the three year period to 1992. All pillar extraction fatalities in the preceding decade have also been reviewed. This was the first occasion that these reports had been assembled and analysed as one entity.

One conclusion from this analysis was the lack of application of engineering science principles in the investigations. Many investigations failed to report basic parameters such as depth, mining height, panel width, panel retreat distance and strata lithology. The role of pillar width to height ratio, w/h, and panel width to depth ratio, W/H ,in determining pillar behaviour and failure mode has already been noted. Such parameters assume greater significance in pillar extraction because pillars are being deliberately reduced in strength to the point of failure and because extraction is continuously changing the ratio of coal pillar stiffness to surrounding strata stiffness on a local and a regional basis.

In establishing the fundamental causes of strata instability in pillar extraction, it is important to step back from the micro-environment, i.e., the face area and overview the macro-environment, i.e., the panel/mine system. For example, many of the buried continuous miners were attributed to Stook X being too small. However, there were many situations similar to these where the primary cause was attributed to Stook X being too large!

Table 2 lists some of the issues recorded as the contributing causes in the 44 investigation reports studied in detail. When reviewed overall, the philosophy of US loss prevention engineer, Bill Doyle, may appear confirmed; that is "for every complex problem there is at least one simple, plausible, wrong solution". However, these issues all had some impact on the specific accident they relate to and the later statement by Kletz (1988) may be more appropriate:

"I am not suggesting that the immediate causes of an accident are any less important than the underlying causes. All must be considered if we wish to prevent further accidents, ... But putting the immediate causes right will prevent only the last accident happening again; attending to the underlying causes may prevent many similar accidents".

Many of the issues contained in Table 2 are symptomatic of past accident investigation techniques whereby the focus has been on active failures, i.e., deviation from stipulated rules. Few investigations have focussed on latent failures, i.e., appropriate design for the conditions. This focus requires a knowledge of fundamental engineering science principles.

Table 3 presents some facts and figures arising from a more in-depth analysis of the 44 incidents. The following significant points have emerged from further analysis of these accidents:

- Over 70% of the incidents were associated with subcritical to critical panel dimensions.
- 64% occurred while taking the first or last lift off a fender, i.e., as the mining operation was retreating through an intersection.
- 50% of the victims were waiting in intersections.
- 66% of buried continuous miner incidents were associated with a 2 to 4m weak immediate roof overlain by a massive competent roof.
- 49% were involved with an extended time delay during extraction.
- 33% of fatalities occurred at shallow depth (<50m) which is disproportionately high given that such operations represent less than 10% of total pillar extraction production.

Table 2. Some of the Issues Recorded as Contributing Causes in 44 Incidents of Buried Continuous Miners.

ISSUES IDENTIFIED	**FREQUENCY IN ACCIDENTS**
ANGLE OF LIFT	5
WIDTH OF LIFT	3
OFF LINE DRIVAGE	4
LENGTH OF LIFT	5
FORMING TOO SMALL A STOOK	6
EXCESSIVE COAL IN GOAF	12
INTERSECTION SIZE (TOO LARGE)	3
VENTURING INTO GOAF TO REDUCE STOOK SIZE	7
PRE-SPLITTING OF PILLARS	4
FENDER INSTABILITY	7
OVERLYING WORKINGS	2

The analysis indicates that the majority of mishaps are associated with latent or design issues. Three of these underlying causes relate to:

- The dimensioning of panel widths and mining layouts without due regard to controlling abutment stresses.
- The sudden mode of failure of shallow workings having large W/H ratios.
- The accelerated failure mode of weak roof under large mining spans.

Many accident investigations have focussed on the manner in which mining operations have been conducted in the vicinity of intersections. Issues such as spans, roof bolting and strapping, breaker lines, lead in timber and stook sizes come in for careful attention. However, whilst appropriate given the statistics, intersections often represent immediate causes rather than underlying causes. Intersections are the weakest structural element in the mining system. Other latent failures therefore tend to first manifest themselves at intersections.

Identification of the latent causes of failure may enable them to be engineered out in the design process. If this is not possible, it at least improves the confidence level in anticipating potential problems and in incorporating effective controls and barriers in Risk Assessment and Hazop processes.

Some of the issues identified from the analysis of buried continuous miners require further research to resolve. The critical span required to induce full caving under various lithologies is one example.

Figure 4 shows the effect of panel width to depth ratio, W/H, on the distribution of tensile stresses around total extraction excavations. A very significant point to note is that at shallow depth, zones of tension can extend from the working horizon all the way through to the surface once the W/H ratio exceeds about 1, i.e., the span of uncaved strata equals the depth. At shallow depth, it is not uncommon for W/H ratios to exceed 3 prior to the development of full caving. Furthermore, the strata is likely to be affected by weathering, one effect of which is to reduce the shear strength along discontinuities (joints, faults, etc.) The shear strength along these features is further reduced by the unclamping effect of being located in zones of tension. At shallow depth, the W/H ratio is very sensitive to small changes in overburden cover or excavation width.

Given these basic principles, it could be anticipated that at a shallow depth, failure can be triggered by a small change in dimensions, develop instantaneously and extend through to the surface. Plug failures and windblasts are to be expected.

The disproportionate number of accidents at shallow depth unfortunately confirms this behaviour. Officials who have specifically stationed themselves to watch for signs of impending failure have been caught by sudden falls. Workmen who were looking for warning signs such as rib rush, roof dribbling and props loading up, have been taken by surprise.

An awareness of the fundamental engineering principles governing behaviour at shallow depth can find widespread application at the minesite. Some examples are:

Design

- Additional airways to dissipate windblasts.
- Panel dimensions which minimise area of standing goaf prior to failure.
- Layouts which start panels against discontinuities to encourage early goafing.
- Remote controlled continuous miners.
- Mobile breaker line supports.

Control

- Motivation to keep the panel tidy to minimise windblast debris.
- Keep all loose materials well back from the face.
- Motivation to keep away from goaf edges.

ADVANCED COAL PILLAR DEFORMATION BEHAVIOUR

Most of the engineering science principles presented in this paper are elementary. Figure 5 illustrates an example of how the SCCMD Project is applying advanced versions of these to develop the theoretical knowledge base on pillar deformation behaviour. The figure illustrates the influence of the stiffness of the mining system on fender behaviour in Wongawilli pillar extraction at depths of 200m and 500m.

The mining layout and geological properties are identical in both cases. Fenders fail at the same load. However, the manner in which they subsequently shed load, or yield, is significantly different. For example, a 7m fender yields more rapidly at 200m depth compared to the same fender at 500m depth.

As the depth of mining decreases, the thickness and stiffness of the roof strata are reduced. The roof is less capable of transferring load from the fender onto the panel abutments. In this softer system, the roof "chases" the fender, causing it to yield more rapidly.

The example highlights the potential pitfalls if field measurements and performance assessments are not underpinned by engineering science principles. The cases presented assume that all the load is carried by the fender and the abutments. Caving goaf reconsolidation are currently being incorporated into the analysis to take account of the load carried by reconsolidated goaf. These developments find wider application. In longwall mining, for example, they can be applied to:

- Chain pillar design and behaviour.
- Quantifying the dynamic behaviour during holing operations of predeveloped longwall recovery roadways.

UTILISING NEW TECHNOLOGY

New technology offers the potential to improve safety by engineering many problems out of the mining system and/or engineering barriers or controls into the mining system. Remote controlled continuous miners and mobile breaker line supports (MBLS) are an example of each application in the case of pillar extraction.

The introduction of new technology, however, also needs to be underpinned by engineering science. In the space of just over 12 months to 1992, 10 fatalities involving remote control machines occurred in the USA underground coal mining industry. MBLS's have been buried on numerous occasions in New South Wales pillar extraction operations and a number have had to be abandoned in the goaf.

Figure 6 shows one instance where a remote control continuous miner was buried in a New South Wales pillar extraction operation which utilised MBLS's. It is interesting to apply some basic engineering science principles to this case.

- Based on Equation (2) or (3), a stook measuring 6m long x 3m wide x 2.7m high is capable of supporting 11600 tonnes or 11200 tonnes respectively.

- Even if this capacity is reduced by 75% to allow for spalling of the stook, the stook still has a support capacity of more than 3 times that of a pair of MBLS's.

- Stooks are located towards the centre of unsupported spans where they have the most beneficial effect on roof control, whilst the MBLS's are located close to the ribside where their support resistance has a much lesser effect on controlling roof convergence.

- Stooks provide continuous resistance to roof convergence since they are formed in-situ, whilst MBLS's provide cyclic resistance.

Clearly there is still a role for stooks when MBLS's are utilised in weak laminated roof strata. The stook associated with the buried continuous miner in Figure 6 is too small to limit the effective span of the weak mudstone roof. This span, measured from the tip of the inbye MBLS to the far ribline, is close to 12.5m. According to Equation (5), the maximum convergence of a 12.5m roof span will be almost 19 times that of two 6m spans separated by a substantial Stook X. Further, for reasons already noted, roofbolts can provide a false sense of security when spans are large relative to roofbolt length.

PILLAR MECHANICS WORKSHOPS

It is a high priority of the SCCMD Project to progressively transfer research outcomes to the coal face. In May 1994, the Project ran a two day workshop on coal pillar mechanics. The workshop, entitled "Stage 1 - Fundamental Principles and Practice" was structured in the following manner:

1. Historical Reviews

2. New South Wales Field Performance Review

3. Fundamental Engineering Science Principles

4. Application of Engineering Science Principles to Face Operations

5. Hands on 'live' case study design exercises.

The response to this Workshop resulted in it having to be re-run in June and again in July. It appears two more re-runs may be necessary. A significant and relatively unique feature of these hands-on workshops is the blend of participants, Table 3.

The response of one supervisor summarises the motivating effect which an improved education on engineering science can have on changing safety culture.

> *"Its got me thinking about the effects of everything I do on the job."*

CONCLUSIONS

Safety is an attitude and changing safety culture is about changing attitudes. However, the best attitudes, systems and technology for improving safety may meet with limited success unless they are founded on sound engineering science principles.

Education in these principles acts as a motivator for changing attitudes. It provides understanding for the Do's and Don'ts, motivation for compliance and direction for dealing safely with new or unexpected situations. Education facilitates an accident investigation focus on latent (design) issues rather than on active (failure to comply with rules) or immediate issues. This focus is required to identify the root causes of accidents and so implement effective remedial actions for all future circumstances.

BIBLIOGRAPHY

BIENIAWSKI, Z.T., 1983: New Design Approach for Room and Pillar Coal Mines in the U.S.A. Proceedings of 5th Int. Conference Rock. Mech. Aus. I.M.M. - Melbourne, 1983.

GEORGE, N.H., 1942: The Principles of Safety.
Quebec Metal Mines Accident Prevention Association.

KLETZ, T., 1988: Learning From Accidents in Industry. Butterworths, London, Boston.

SALAMON, M.D.G. and MUNRO, A.J., 1967: A Study Of The Strength of Coal Pillars. J.S. Afr. Inst. Min. Metall., Vol. 68, No. 2, pp.55-67.

SALAMON, M.D.G. and ORAVECZ, K.I., 1975: Rock Mechanics in Coal Mining. Chamber of Mines of South Africa. P.R.D. Series No. 198, 1975.

Safety Factor	Probability of Stable Workings	Probability of Stable Workings
	(Observed)	(Predicted)
0.6	0	0.6
0.7	0	0.66
0.8	11.11	7.99
0.9	18.52	25.34
1	44.44	50
1.1	59.26	72.59
1.2	81.48	87.48
1.3	96.3	95.08
1.4	96.3	98.3
1.5	100	99.47

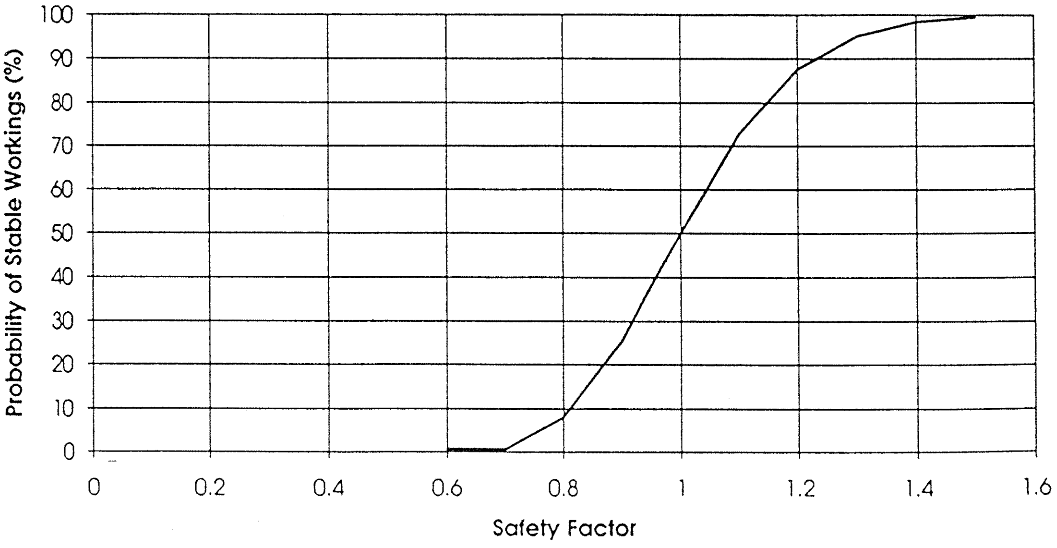

Figure 1. Probability of Stability Associated with Salamon and Munro Safety Factors

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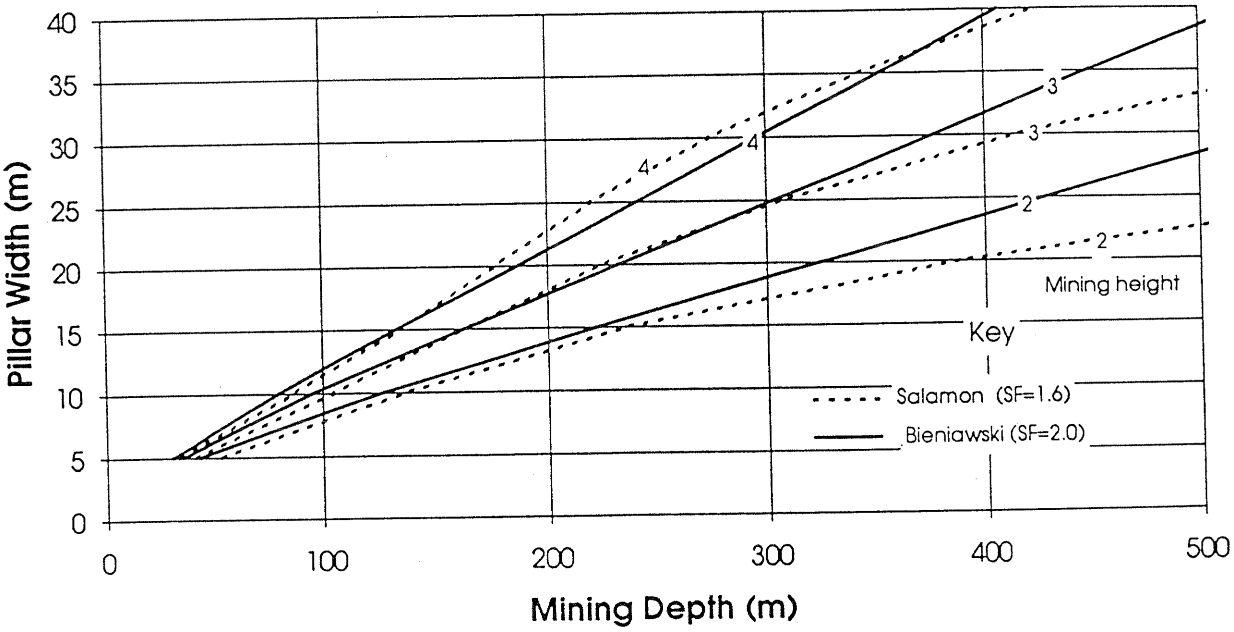


Figure 2. Comparison between a Salamon Factor of 1.6 and a Bieniawski Safety Factor of 2.

Table 1. Safety Factors Associated With Collapsed Bord and Pillar Workings in Australia.

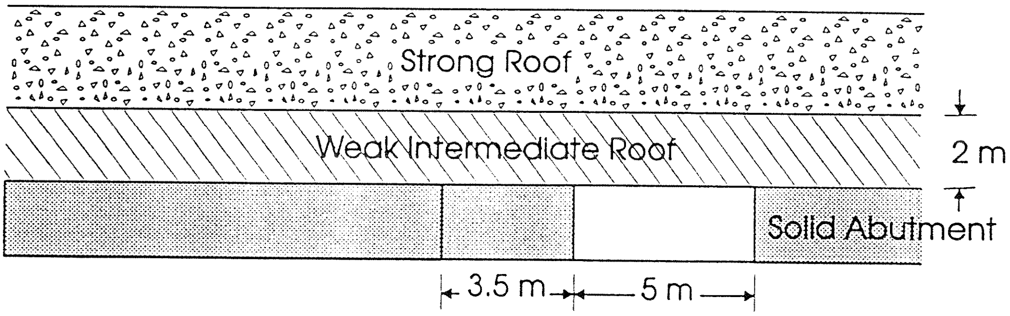
Depth (m)	Min. Ht (m)	(Pillar) Width / Height	Collapse Event	Safety Factor	
				Bien.*	Sal.†
60	2.7	1.3	Sudden Collapse. Major windblast triggered by goaf abutment loading.	1.01	0.97
75	4.5	1.8	Progressive deterioration then surface subsidence.	1.31	1.13
80	7	1.1	Sudden collapse. Major windblast.	1.35	1.07
80	3	2.5	Sudden collapse. Major windblast.	1.08	1.0
95	1.8	2.0	Unknown, feather edges at extent of collapsed area.	1.3	1.07
100	6	1.7	Sudden collapse. Major windblast.	1.46	1.27
120	4.5	2.2	Sudden collapse.	1.0	0.88
140	5	3.0	Progressive deterioration then collapse.	1.4	1.15

* Bieniawski † Salamon

Table 3. Buried Continuous Miners - Some Facts and Figures.

Type of Mining Operation	
• Driving first workings	3
• Driving pillar extraction secondary development	2
• Lifting off pillars	39
Position in Mining Sequence	
• Taking first or last lift off a fender	64%
Extent of Machine Burial	
• 0-30%	1
• +30% - 60%	3
• +60% - 80%	9
• +80% - 90%	7
• +90%	24
Frequency of Driver's Cab Being Buried	
• 25/44 = 57%	
Height of Fall Above Working Roof	
• 0-3m	66%
• 3 - 6m	17%
• Full Goaf	17%
Warning of Impending Fall	
• No	37%
• Yes	63%
Stooks and Fenders	
• Frequency of crushing and over-running:	
Total	55%
Fatal Accidents	60%
Location of Victims	
• Driver on board continuous miner	0
• Driver running from continuous miner	3
• Adjacent to continuous miner	3
• Ribline of intersection outbye of face	6
Prior Activity of Victims	
• Driving continuous miner	3
• **Face Active:** Directly engaged in face operation (inc. acting as cockatoo)	1
• **Face Passive:** Not directly engaged in a face operation of which	8
• **Face Passive:** On ribline of intersection	6
Miner Drivers	
• Protected inside cab	5
• Protected but requiring extended rescue	3
Remote Control Continuous Miners	
• No	31/33
• Yes	2/33

a) Cross-Sectional View-No Stook



b) Plan View-Stook X

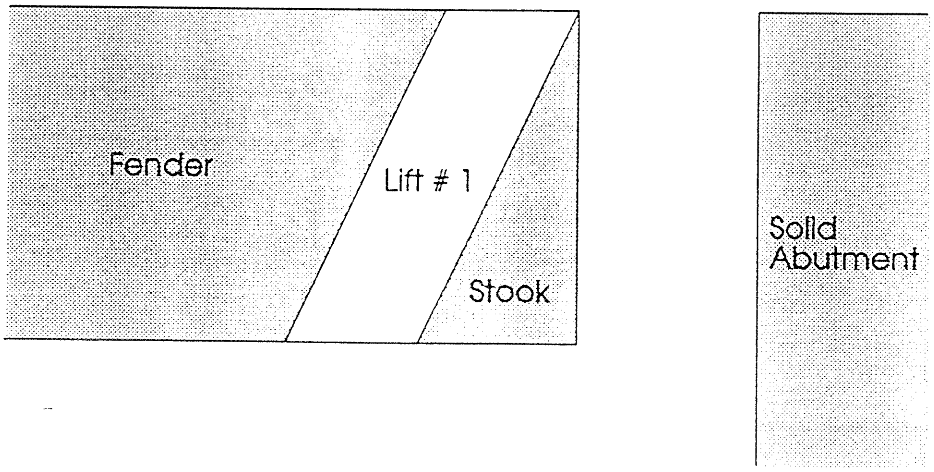


Figure 3. A Situation Where a Weak Immediate Roof Is Overlaid By A Stiff Roof Stratum

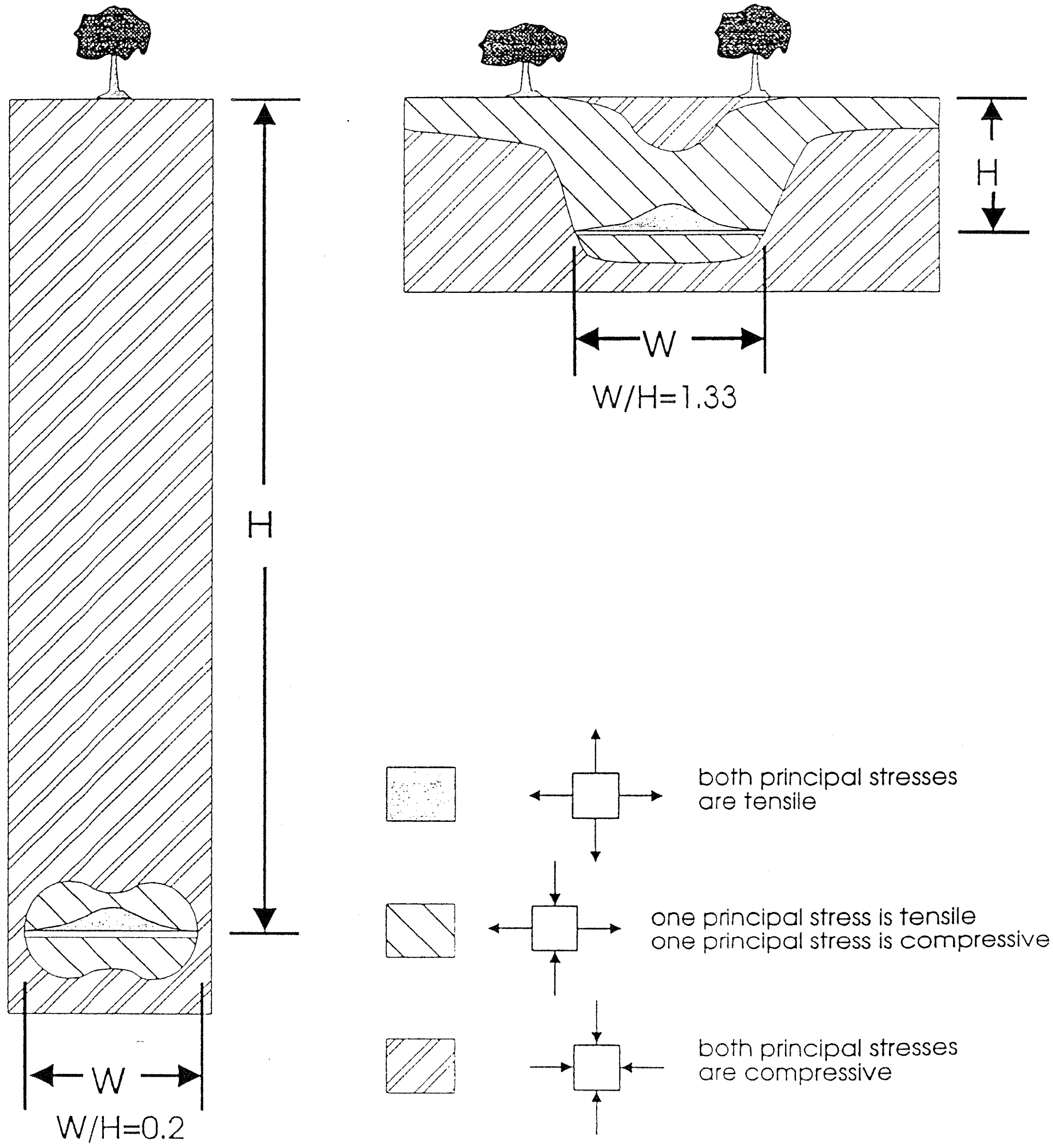


Figure 4. Tensile Stress Zones Around Isolated Panels at Shallow and Great Depth.

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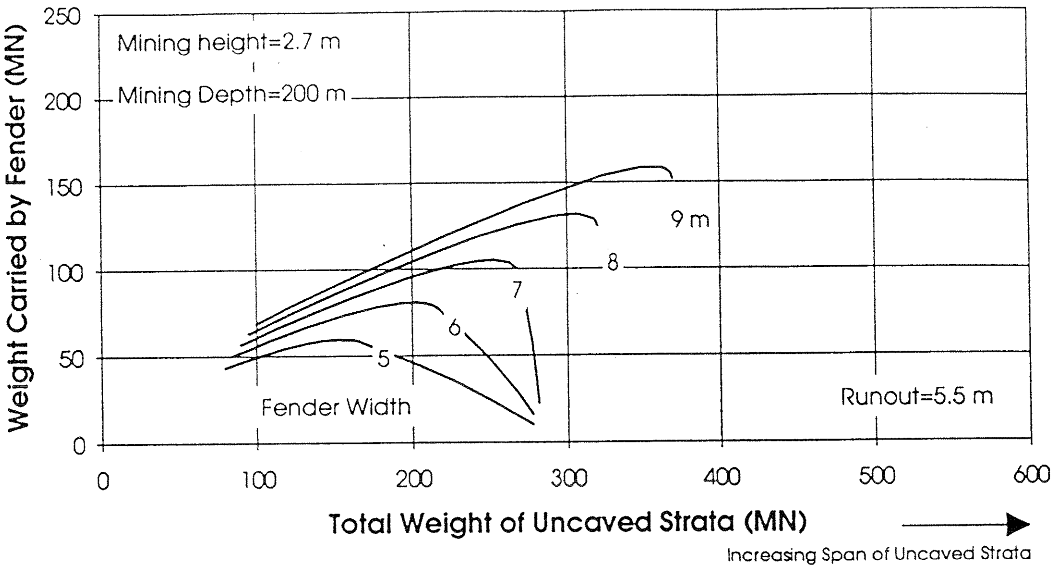

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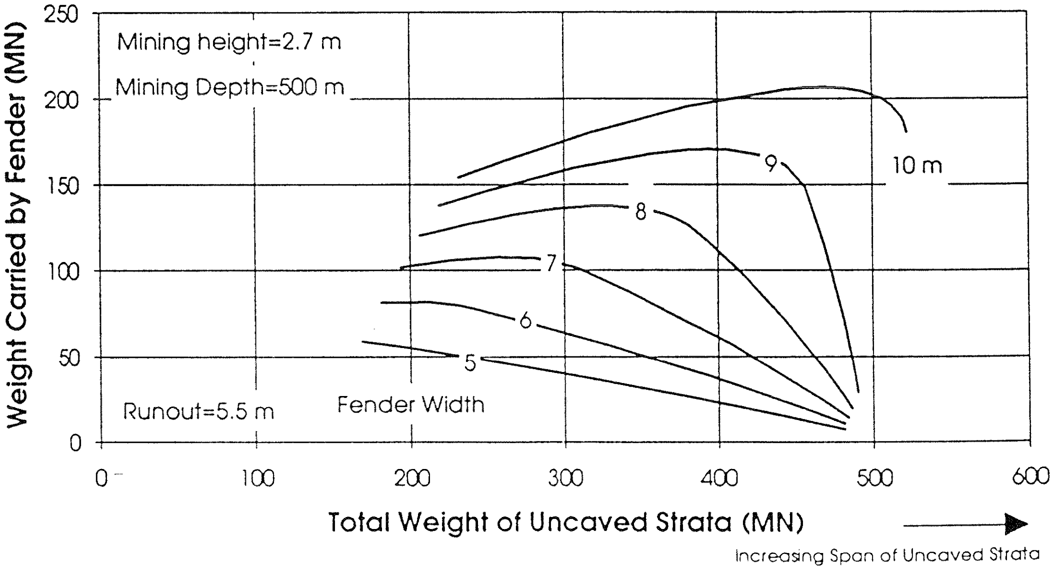

Figure 5. Wongawilli Fender Behaviour for Mining Depth (a) Equal to 200m and (b) Equal to 500m.

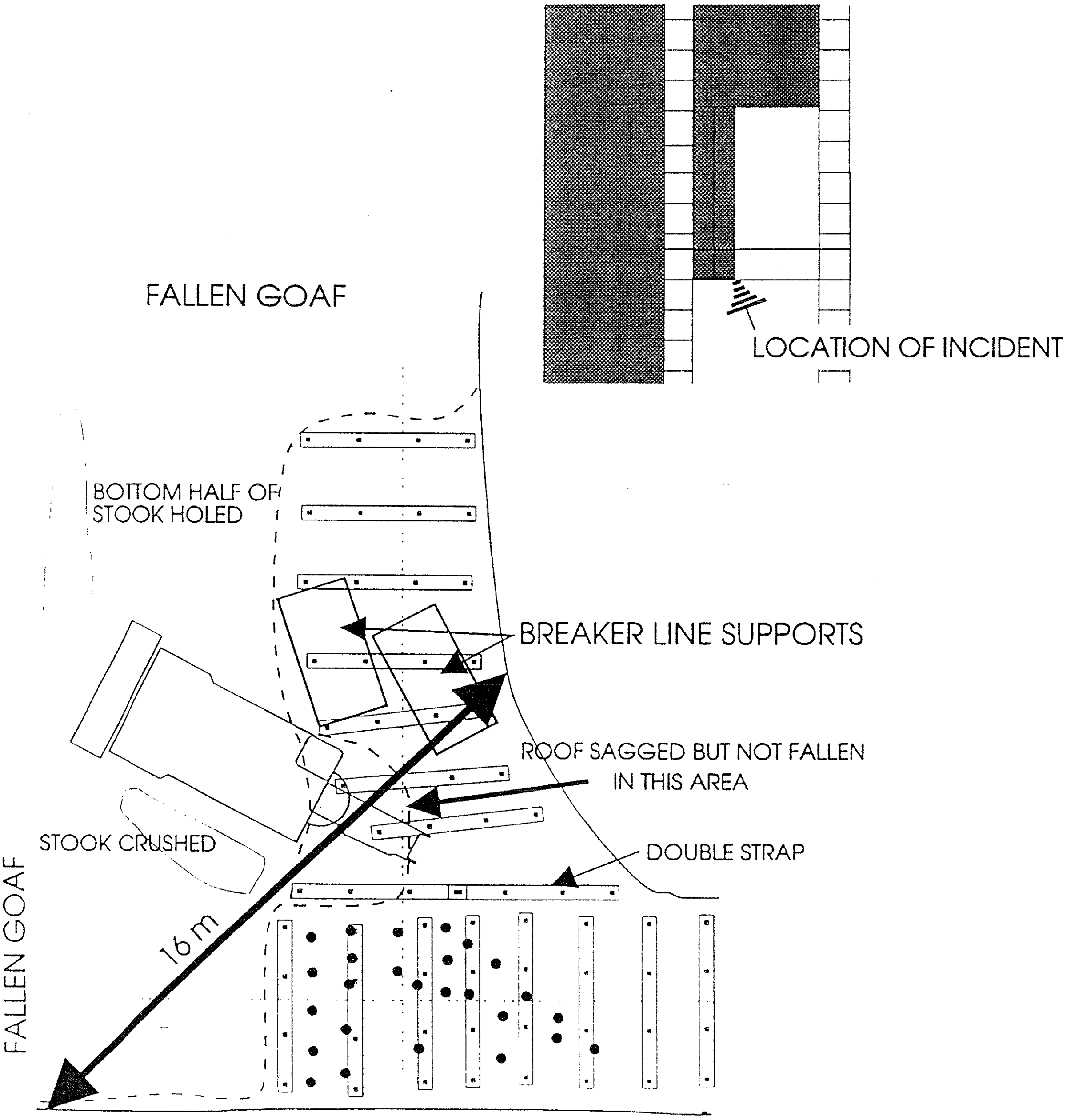

Figure 6. An Operation Using a Remote Controlled Continuous Miner and two MBLS where the Continuous Miner was Buried by a Roof Fall.

Table 3. Classification of Participants in Pillar Mechanics Workshops.