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Coal pillar design when considered a reinforcement problem rather than a suspension problem

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ABSTRACT

Current coal pillar design is the epitome of suspension design. A defined weight of unstable overburden material is estimated, and the dimensions of the pillars left behind are based on holding up that material to a prescribed factor of safety. In principle, this is no different to early roadway roof support design. However, for the most part, roadway roof stabilisation has progressed to reinforcement, whereby the roof strata is assisted in supporting itself. This is now the mainstay of efficient and effective underground coal production. Suspension and reinforcement are fundamentally different in roadway roof stabilisation and lead to substantially different requirements in terms of support hardware characteristics and their application. In suspension, the primary focus is the total load-bearing capacity of the installed support and ensuring that it is securely anchored outside of the unstable roof mass. In contrast, reinforcement recognises that roof de-stabilisation is a gradational process with ever-increasing roof displacement magnitude leading to ever-reducing stability. Key roof support characteristics relate to such issues as system stiffness, the location and pattern of support elements and mobilising a defined thickness of the immediate roof to create (or build) a stabilising strata beam. The objective is to ensure that horizontal stress is maintained at a level that prevents mass roof collapse. This paper presents a prototype coal pillar and overburden system representation where reinforcement, rather than suspension, of the overburden is the stabilising mechanism via the action of in situ horizontal stresses. Established roadway roof reinforcement principles can potentially be applied to coal pillar design under this representation. The merit of this is evaluated according to failed pillar cases as found in a series of published databases. Based on the findings, a series of coal pillar system design considerations for bord and pillar type mine workings are provided. This potentially allows a more flexible approach to coal pillar sizing within workable mining layouts, as compared to common industry practice of a single design factor of safety (FoS) under defined overburden dead-loading to the exclusion of other relevant overburden stabilising influences.

1. Introduction

The simplest model for coal pillar loading consists of an unstable overburden to surface, known as Tributary Area Theory (TAT), overburden stability then being entirely controlled by the load-bearing ability of the coal pillars formed in the workings (Fig. 1). Whilst for bord and pillar-type mining design purposes, the TAT model to surface has been and can be modified (by the application of either pressure-arch concepts or by considering the sub- or super-critical nature of the overburden at surface) to modify pillar loading magnitudes, it is still generally true to state that the stability of coal pillars is evaluated via a defined unstable section of overburden imparting dead loads onto the coal pillars beneath. The level of confidence in the design remaining stable is then determined according to the design FoS over and above the assumed coal pillar strength(s).

Since the Coalbrook disaster in 1960, the basic model of full TAT to surface has been applied in empirical studies attempting to define the strength of coal pillars by back-analysing failed cases, including Salamon and Munro in the direct aftermath of Coalbrook. Fig. 2 shows how pillar loading can be modified according to panel width to cover depth considerations (W/H ratio) as part of what may be termed as partial TAT [1,2]. In both cases, vertical dead-loading of the overburden onto the coal pillars is the key pillar design assumption.

Van Der Merwe makes the following statement in relation to what occurred in the immediate aftermath of Coalbrook:

The attention was focused on pillar strength research, very little attention initially being paid to overburden strength. This is not an

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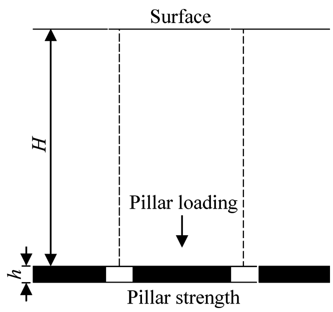

Fig. 1. Tributary Area Theory (TAT) loading arrangement for coal pillars.

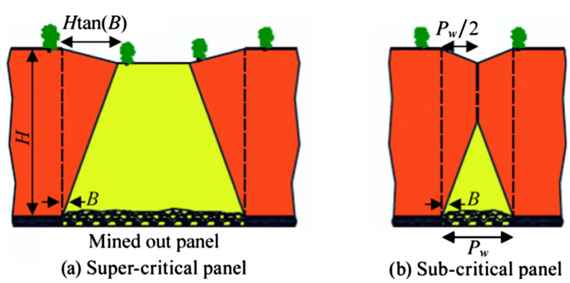

Fig. 2. Abutment angle concept used to estimate loads in ARMPS [2].

unreasonable approach: if the pillars are strong enough to support the overburden, it doesn't matter how weak the overburden is—failure cannot occur. This is especially true if the [TAT] is used to determine pillar load because TAT predicts the maximum load on the pillar [3].

The fact that this statement was made as recently as 2006, over 40 years after Coalbrook, is taken to be evidence that the TAT pillar loading model has persisted, whether it be full TAT to surface (as is being described by Van Der Merwe) or a modified/partial version as in the case of studies by Mark et al. [2,3].

At the 35th ICGCM, Reed, McTyer, and Frith posed a question, asking whether it was possible for coal pillar research to follow what had already occurred in roadway roof control research [4]. Roadway roof control was initially founded on the belief that roadway roof support needed to be designed to hold in place an otherwise critically unstable roof mass, using suspension roof support (Fig. 3a). However, this was eventually superseded by the prevailing concept that roadway roof stability could be far more efficient and reliable by retaining some or all of the self-supporting ability of the roof strata via reinforcement using roof bolting and longer cables and tendons (Fig. 3b). The reinforcing approach considers the competence of the roof mass (as given by the Coal Mine Roof Rating or CMRR for example), the horizontal stresses acting across the roof, the width of the roadway and the installed roof support in formulating design outcomes. The roadway roof stability design problem was forever changed from the simple and often far too simplistic assumption of "dead-load" suspension when the problem became one of roof reinforcement. Frith and Colwell outline details of the various problems and potential risks of continuing to apply a dead-load suspension approach to roadway roof support design in reinforcing design situations [5].

This paper debates the application of full or modified TAT dead-load pillar loading to bord and pillar coal pillar design as the founding mechanistic assumption nearly 60 years after Coalbrook. Fig. 1 shows the suspension arrangement for coal pillars. The similarity with Fig. 3a for roadway roof support is evident, the only difference being that the unstable strata mass is held in place by roof bolts anchored into stable overlying strata, as compared to a coal pillar being founded on the floor of the roadway.

In stark contrast, Fig. 4 outlines a suggested reinforcing problem representation for coal pillars similar to that shown Fig. 3b for the roof of a mine roadway. In the reinforcing coal pillar design representation, the horizontal stress acting within the overburden, the competence of the overburden in terms of its self-supporting ability across the panel, and the panel width are all brought into the problem representation. These are directly analogous to the horizontal stress in the roof of a roadway, the competence of the roof strata (e.g., the CMRR), and the roadway width, respectively. Each is a primary variable in the reinforcing roadway roof stability problem.

This then leads to the fundamental question as to whether, albeit with many years of hindsight, the mechanics of coal pillar design are comparable to that of reinforcing roadway roof support. Do coal pillars control the overburden through reinforcement rather than suspension? Do pillars work to allow the overburden to stabilise itself, rather than simply support the overburden?

The paper seeks to demonstrate that the overburden reinforcement scenario is the more likely answer in many instances with some specific exceptions and offers views on the implications on bord and pillar layout design involving coal pillars.

2. Justification of a reinforcing approach to coal pillar design

In addressing whether the coal pillar design problem is one of suspension or reinforcement, it must be determined as to which becomes unstable first: the overburden to surface or the pillar? This question is derived by considering suspension design for roadway roof support where by definition, the installed roof support must remain load-bearing well after the roof strata has failed and become critically unstable, a roof collapse the being solely dictated by the structural state and associated load-bearing capacity of the installed roof support.

The earlier quotation from Van Der Merwe implies that as long as the overburden becomes critically unstable before a correctly designed coal pillar reaches its maximum load-bearing capacity, it does not matter how weak the overburden is [3]. At face value this makes perfect sense, but leaves one critical issue unanswered: "will in fact the overburden become critically unstable before the coal pillar goes post-peak"?

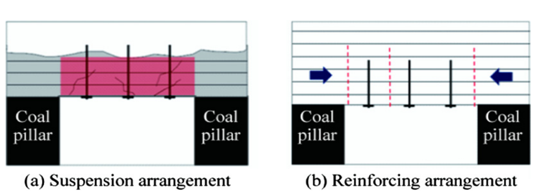

Fig. 3. Schematic illustrations of suspension and reinforcing problem representations for roadway roof control.

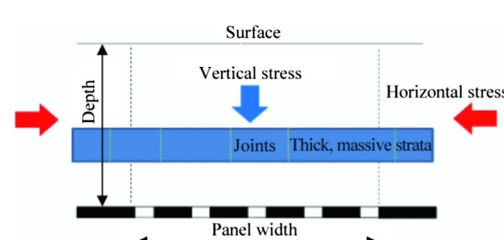

Fig. 4. Schematic illustration of a reinforcing problem representation for coal pillar design.

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