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An Approach to model the strength of coal pillars

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1. Introduction

Underground coal mining constructs hundreds of thousands of coal pillars annually. The industry is dependent upon the stability of these variously sized hexahedrons, and so knowledge of the coal's rock mass strength is imperative. Yet the approach for estimating the rock mass strength of coal has developed along a different path to that for other rock masses.

The typical method for estimating rock mass strength is to empirically reduce the intact rock strength by a factor that accounts for the geological structures in the rock mass (bedding planes, joints, shears, etc). The empirical Hoek-Brown / *GSI* process is one such method.

While the most used methods for estimating the strength of coal pillars are also empirical they are geometrically based. The intact strength of the coal, the in situ stress and the geological structures of the coal rock mass may be implicit in these geometrically-based methods, but their relative impact is unknown and largely unquantifiable. These geometrically-based methods are seemingly at odds with the common methods of estimating rock mass strength.

This paper first collates a coal pillar database from Australia, South Africa, USA and India and then presents the results of numerical analyses carried out on the cases. Appropriate strength parameters and an approach to model coal pillars is then proposed.

2. Pillar cases

Although coal is known in most geological periods, the bulk of the world's coal deposits were formed during two main periods of geological history: the Carboniferous in the northern hemisphere about 300 million years ago, and the Permian in the southern hemisphere about 50 million years later.[1]

Northern hemisphere coals were formed in conditions conducive to the formation of coals rich in vitrinite and low in mineral matter content. In contrast, the Permian swamps of the southern hemisphere existed in cold conditions related to the ending of a massive ice age. Slow growth allowed the intrusion of fine inorganic material, present today as the high-ash component of the coal. So there is a broad difference in coals from the northern and southern hemispheres, the latter being typically of higher ash content.

There are also differences between coals from the same geological age. South Africa is noted for its high ash, generally lower sulphur, and lower-energy thermal coals. The dominant product from underground coal mining in New South Wales, Australia is a soft-coking, high-volatile coal.[2] Indian coal has high ash content, medium to high volatile matter and low calorific value.[3] At the outset therefore, it would be reasonable to expect each region to exhibit different coal properties based on the genesis of the deposits.

The published data relating to coal pillars comes largely from Australia, South Africa, the USA and India.

2.1. Australia

A series of mine design accidents in the late 1980s resulted in a research program at the University of NSW Australia (UNSW Australia or UNSW) aimed at developing pillar design guidelines.[4] The database comprises eighteen failed (also termed 'collapsed') and fifteen stable (also termed 'un-collapsed' or 'intact') coal pillars.[5]

Based on this database and the earlier work of Salamon and Munro in South Africa,[6] Galvin et al. [4]developed empirical relationships to estimate coal pillar strength, C_p, as a function of pillar geometry, w/h. The linear version of those relationships for the combined Australian and South African database is

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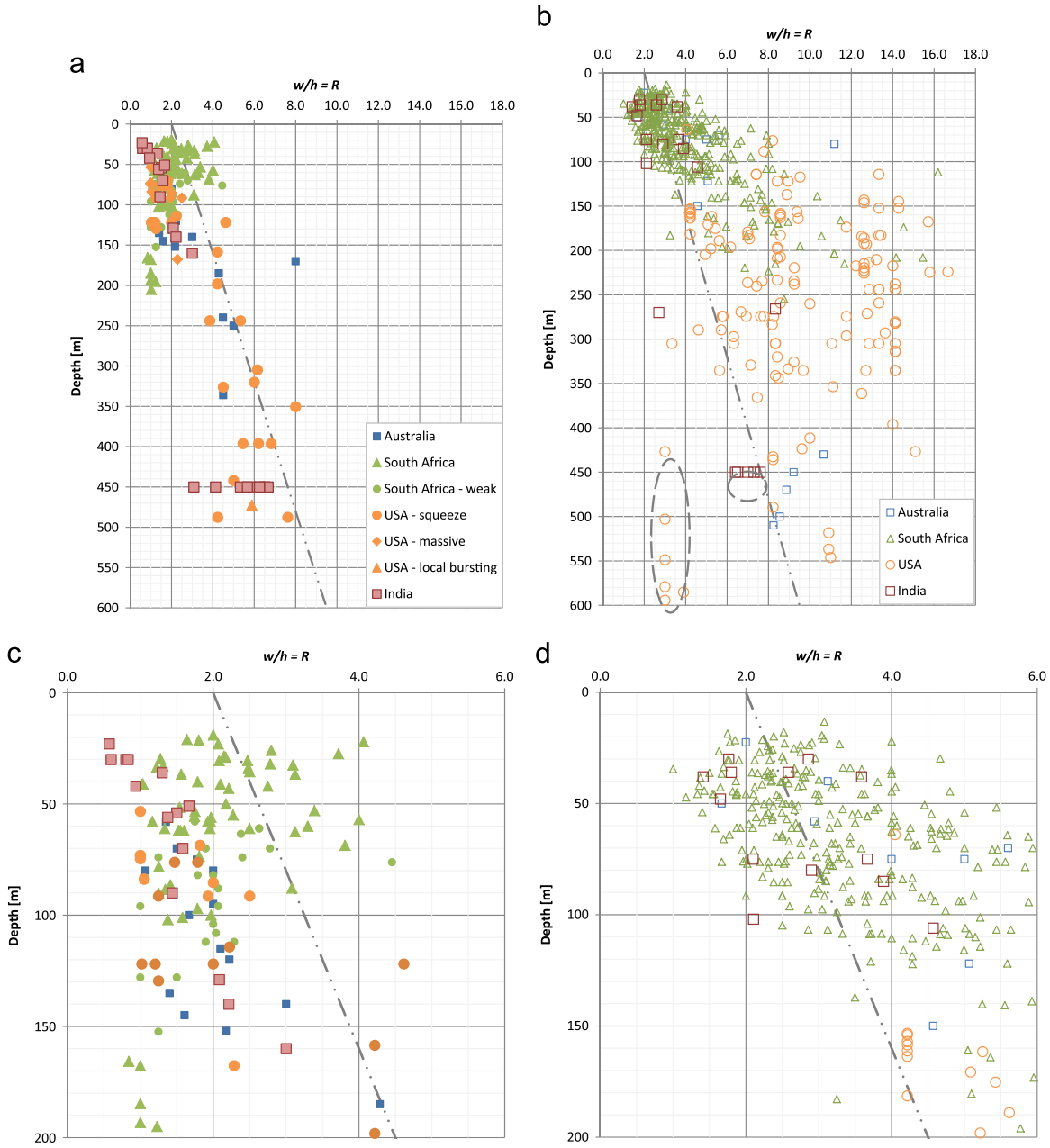

Fig. 1. (a) The combined collapsed (left) and (b) un-collapsed (right) database. The circled cases are the yielding pillars from Jitpur, India and the highly rectangular pillars from Utah, USA. The bottom plots (c) and (d) are subsets of the database focussing on the cases below 200 m depth. The line shown is w/h=2.0 + 0.0125 x *depth*.

$$C_p = 5.12\left(0.56 + 0.44\frac{w}{h}\right)[\text{MPa}] \quad (1)$$

Although the relationships are said to be applicable for $w/h \leq 8$, only one of the collapsed pillars in the Australian database has a ratio $w/h = 8$; the others having $w/h < 5$ (see Fig. 1). While the authors consider that Galvin[a] convincingly argues the validity of the $w/h = 8$ case, others have questioned it.[8,9]

2.2. South Africa

The most recent database of South African coal pillar experience is that collated by van der Merwe and Mathey.[10] It comprises 86 collapsed cases and 337 un-collapsed cases. It is important to appreciate that no pillar failure has been recorded in South African collieries with a w/h ratio greater than 4.45.[11]

Also of interest is the finding of Mathey and van der Merwe[12] from their analysis of 1800 laboratory tests that there are no significant differences in strength properties between South African coal seams.

2.3. USA

The USA National Institute of Occupational Safety and Health (NIOSH) collated 645 case histories of retreat mining workings. It makes these data available as part of its Analysis of Retreat Mining Pillar Stability (*ARMPS*) software.[13] That data has been filtered by the authors to include only those one hundred seventy cases of development workings, in order to equate the USA database to the bord & pillar workings of the Australian and South African cases. The filtered database comprises thirty-five collapsed cases and one-hundred thirty-five un-collapsed cases.

NIOSH distinguishes failure type and defines 'massive collapses' as pillar failures that take place rapidly and involve large areas. It is worth noting that all the eleven cases defined as massive collapses, involved