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Strength reduction on saturation of coal and coal measures rocks with implications for coal pillar strength

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ABSTRACT

Coal and associated coal measures rocks, including shales, mudstones and sandstones, may lose significant strength on water saturation due to the absorption of water, stress corrosion or mineralogical changes to the clays within the rock matrix. As most coal seams are natural aquifers, water ingress into underground mine workings is common, and is typically controlled during mining by dewatering pumps. After a mine has closed, unless ongoing pumping is maintained, workings will flood and coal pillars and the pillar roof and floor foundations will revert to fully saturated conditions. This paper reports on a study of how flooding effects pillar strength in an abandoned coal mine in Queensland, Australia. The reduction in strength of coal and coal measures rocks between unsaturated and saturated water moisture contents has been quantified through physical testing. These strength data, along with the distribution of lithologies in a coal pillar from the mine, were used as inputs for numerical modelling of the strength reduction of a coal pillar on water saturation. It was found that the modelled pillar strength reduction could be estimated by the average strength reduction of all the lithological components of the pillar, weighted by the thickness of each lithology.

1. Introduction

Increasing moisture content in sedimentary and coal measure rocks has been associated with a reduction in their strength and compliance as measured in laboratory tests [1–4]. Moisture content has also been indirectly associated with roadway instability in working and closed mines [5,6] and pillar and floor failure during the inundation of closed collieries [7,8]. For example, an increase in coal mine roof falls during summer months is attributed to an increase in humidity and the associated reduction in roof rock strength [9–12]. The American Mine Safety and Health Administration (MSHA) issue alerts with the approach of summer warning of roof instability related to the higher humidity during this period [10,11].

Coal pillars retained to support the roof in partial extraction bord-and-pillar mining are likely to contain interseam "stone" and roof and floor rocks will almost certainly to be from the coal measure rock types, such as sandstones, mudstones and siltstones, claystones, shales and volcanic tuffs. As most coal seams are aquifers, moisture levels in the pillars and surrounding rocks will be reduced during mining from fully saturated conditions and the strength of pillars formed may slowly increase. On mine closure, workings will typically flood as natural groundwater equilibrium is re-established and the coal and pillar component rocks will revert to their fully saturated strengths.

Extensive pillar failure has been associated with water rising in abandoned iron ore mines in the Lorraine Basin in France, and in anhydrite and gypsum mines in Italy [7,8], and rising water is associated with floor failure resulting in mine collapse with damaging surface subsidence in America [13,14].

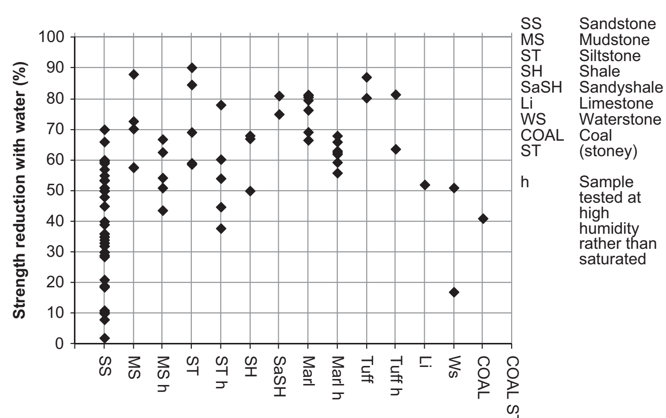

Fig. 1. Percentage UCS strength reduction with water saturation or with high (90–100%) humidity (subscript "h") for a variety of rock types. Data from various sources, see Table 9.

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The focus of the study reported in this paper is directed toward quantifying the effect of rising ground water on coal pillar stability as estimated by a factor of safety (FoS) defined as the ratio of estimated pillar strength to average axial pillar stress. Under investigation is a colliery located in Queensland, Australia that was closed in 1987, and since closure has been allowed to flood.

A feature of the mine under investigation was the thickness of the coal seam that resulted from the coalescing of two Triassic-aged seams with a combined thickness of up to 18 m. A maximum thickness of 11 m of coal was mined in places, although the average mining height was approximately 6.1 m, with 5 m wide roadways and diamond shaped pillars with an average effective width of approximately 20 m.

Surface to seam drilling in 2011 retrieved samples of coal and “stone” from several pillars allowing a testing programme to be undertaken aimed at quantifying the strength reduction that could be expected with re-saturation of the pillar.

In this paper, the findings of the laboratory testing of coal and rock samples retrieved from the pillars are reported. Based on the logged distribution of lithologies in the pillar, roof and floor a numerical model of a “typical” coal pillar is constructed. Rock stiffness and strength parameters are estimated based on an empirical pillar

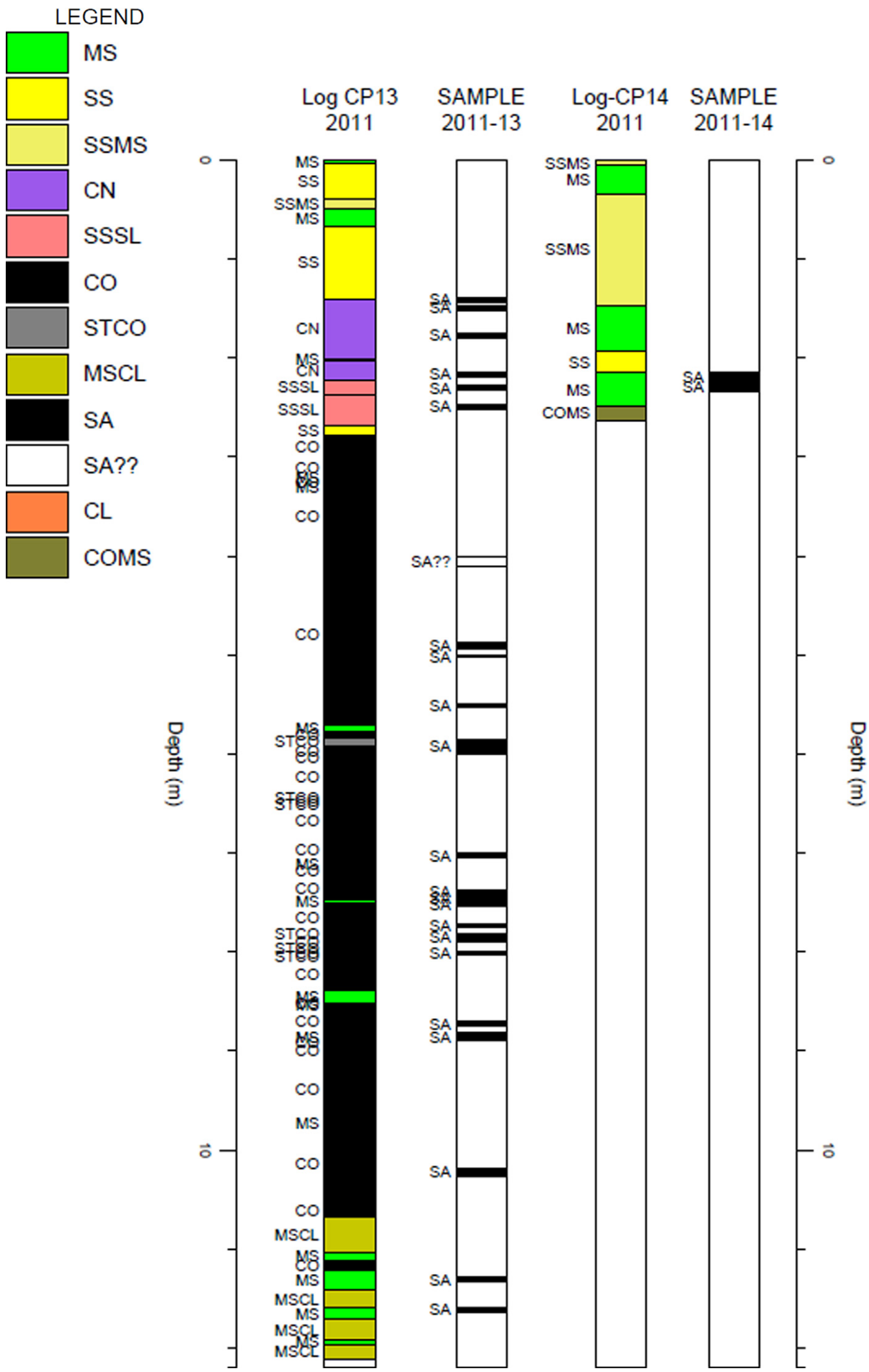

Fig. 2. Holes CP013 and CP014 with identified lithologies and testing sample locations. Correlation between holes is an estimate only.