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Surface subsidence due to underground mining operation under weak geological condition in Indonesia

Takashi Sasaoka [a,*], Hiroshi Takamoto [b], Hideki Shimada [a], Jiro Oya [b], Akihiro Hamanaka [a], Kikuo Matsui [a]

[a] Kyushu University, Fukuoka, Japan
[b] Gerbang Daya Mandari, Samarinda, Indonesia

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ABSTRACT

Subsidence analysis and prediction with measured data have been conducted and applied to local strata and mining conditions worldwide. Underground coal mines chose the most suitable analysis and prediction method for them. However, there was no study based on the measured data of subsidence induced by underground mining operation in Indonesia. This paper describes the condition of underground coal mine in Indonesia and then discusses the subsidence behavior due to longwall mining operation based on measured data in Balikpapan coal-bearing formation in Indonesia.

1. Introduction

Indonesia produced 400 Mt of saleable coal in 2013 with rapid increase in production by almost 99% of surface mining year by year as shown in Fig. 1 (BP, 2013; Indonesia Coal Mining Association, 2014). On the other hand, the rapid increase in production has brought strong concerns on sustainable supply of coal with current quality level in future, due to deepening mining location with increasing stripping ratio, decreasing coal reserve with high quality in the currently operating mines, and constraints on development of surface mine by environmental impact (Matsui et al., 2010). Under this circumstance, the importance of developing underground mines has been recognized in Indonesia, and recently several projects of underground mines have been implemented. However, there is no study based on measured data of surface subsidence induced by underground coal mining in Indonesia. Moreover, the overburden rocks of underground mines in Indonesia are very weak and deteriorated due to water. Therefore, the behavior of subsidence might be different from that in other countries such as Europe, US, Australia, etc. Hence, understanding the behavior of surface subsidence due to underground mining operation is the most important for the assessment of its environmental impact and appropriate underground mine design.

This paper describes the condition of underground coal mines and mining technology in Indonesia firstly, and then discusses the subsidence behavior due to the longwall mining operation based on the measured data in Balikpapan coal-bearing formation in Indonesia.

2. Characteristics of coal measures rocks in Indonesia

Most of the coal deposits in Indonesia are concentrated in Sumatra and Kalimantan. The strata are composed of sediments that are typically found in deltaic and shallow marine depositional environments, such as sandstone, clays and shale. These fresh formations are weak, with the measured rock strengths being much lower than those of most mined coal measures in the world. Coal measures rocks consists of silt stone, mudstone, shale, clay stone, sandstone, etc., and its mechanical properties are generally weak and deteriorated due to water. Especially, the rock containing smectite is very sensitive to water. Fig. 2 shows the histogram of uniaxial compressive strength (UCS) of recovered core (saturated) in KPC coal mine. This figure shows that the coal measures rock is very weak. Fig. 3 represents the slaking characteristics scored by means of the evaluation method of Sadisun et al. (2004). It can be observed from this figure that the slaking index increases with the increasing smectite content. From these results, it can be concluded that the deformation/closure behaviors of roadways are affected not only by ground pressure but also by weathering/slaking phenomenon due to groundwater and moisture supplied by ventilation. Generally speaking, the strength of coal in Indonesia is larger

* Corresponding author. Tel.: +81 92 802 3333.
E-mail address: sasaoka@mine.kyushu-u.ac.jp (T. Sasaoka).

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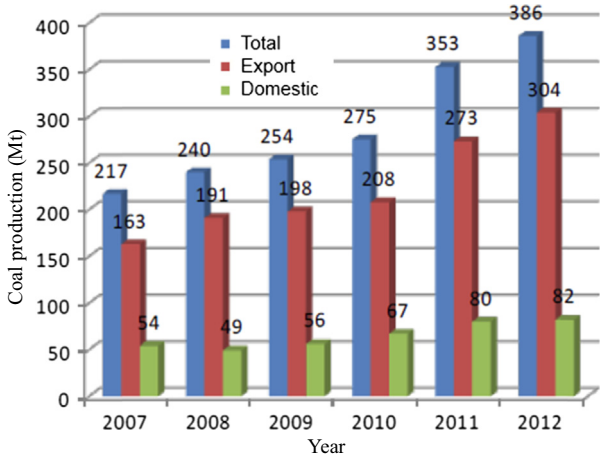

Fig. 1. History of annual coal production in Indonesia (Indonesia Coal Mining Association, 2014).

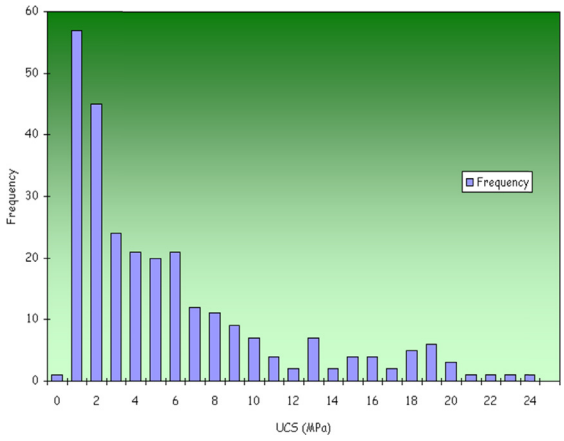

Fig. 2. UCS of core samples in KPC coal mine.

than that of coal measures rock, and it is about 10–20 MPa, which is almost the same as that in Japan.

3. Underground mining technologies in Indonesia

3.1. Privage and support system

Drivage and support system for roadways is one of the important factors for underground coal mine. As drill and blast method is generally applied in small-scale mine, mechanized drivage system is applied in some of the middle-to-large scale coal mines. For example, in Ombilin coal mine, roadheader was used for drivage of entries and roadways in soft rocks, and Dosco-MKII and AM50 were applied for drivage of entries for a longwall panels. Originally, the steel/wooden sets and/or steel arch have been used as support systems. Bolting system has been introduced from Australia since 1994. However, deformation and/or failure behaviors of roadways cannot be controlled only by bolting system in case that development rate is slow and the roadways/entries has to be maintained for longer time, and then additional support have to be installed. Now, the steel arch becomes a major support system again instead of bolting system, indicating that the term of maintaining roadways/entries has an obvious impact on the stability of roadways supported by bolts.

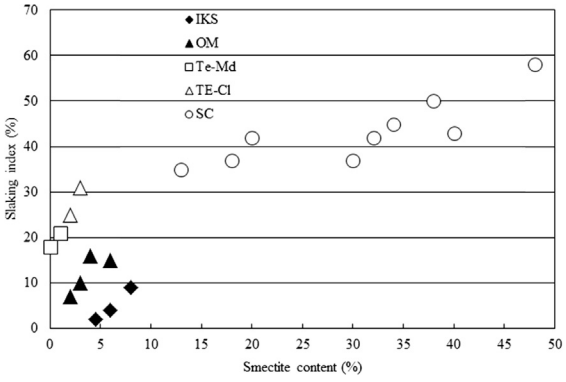

Fig. 3. Relationship between slaking index and smectite content (Sadisun et al., 2004).

3.2. Mining system

In Indonesia, Ombilin coal mine had introduced a fully mechanized longwall mining system. However, the productivity is much lower than that expected. This is because of the dramatic change of coal seam conditions and unfixable face control. Prop and cap mining system has been introduced into the other underground coal mines as shown in Fig. 4. From the points of view of productivity, safety and economics, usual fully mechanized longwall mining system or room-and-pillar mining system by using continuous miner or roadheader should be considered for their introduction. Drivage system with a continuous miner and roof bolt support system has been introduced in Indominco Mandiri by Australian contractor, and coal extraction has been conducted by means of room-and-pillar mining system with BLS (Garcia et al., 2010). In the future, as this mining system may be introduced in small-to-middle scale underground coal mines, the advantage of this kind of fully mechanized mining system may be canceled in case that the dip of coal seam is very steep and the characteristic strength of floor rock is very low.

3.3. Safety and environment issues in underground coal mines in Indonesia

A plenty of accidents had occurred and a great number of lives were lost in underground mining operation. It can be said that the current ground control technique is developed with great loss of life. Today, although many advanced technologies have been introduced in underground coal mining industry, many fatal accidents still occur.

Fig. 4. Steel longwall supports with friction props and articulated caps.