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Technical Note

Effect of bedding plane on prediction blast-induced ground vibration in open pit coal mines

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1. Introduction

The distance and charge weight scaling law has been used for many years to predict the peak particle velocity (*PPV*) of blast vibration. Application of the scaling law is site-specific. It does not elaborate properties of the transmitting medium. Development of finite element wave propagate modeling has provided a tool to predict rock mass responses to dynamic loads.[1,2] A neural network can also be used to predict the blast vibration.[3–5] Despite development of these more sophisticated approaches to predict ground vibration, the scaling law is still the most popular predictor of blast vibration for engineers.[6]

For more than half century the scaling law has been adapted to meet the site-specific conditions as presented in Table 1.[7–10] All relationships still employ distance and charge weight as input parameters. This paper presents a method to include bedding planes in open pit coal mines.

Ground vibration monitoring data were obtained from the two largest open pit coal mines in Indonesia (PT. Adaro Indonesia/Adaro and PT. Kaltim Prima Coal/KPC). These data were used to develop a new relationship in which the effect of bedding planes is included in terms of an incident angle and the number of coal layers.

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2. Location

2.1. Adaro Indonesia

The Adaro mine is located in South Kalimantan in Indonesia. In 2012, Adaro produced 47.2 million tonnes of coal. It has total reserves of 921 million tonnes and resources of 4.7 billion tonnes [11]. Major coal seams have average thickness of approximately 10–60 m and dip of 25–75°. The intervening rocks consist of sandstone, siltstone and claystone with maximum thickness up to 100 m.

Nineteen blasting operations of overburden materials were evaluated in which the ground vibration had been measured at three positions namely side wall, high wall and low wall. The side wall represents vibration propagating perpendicular to the dip direction of the bedding plane. The low wall and high wall represent vibrations passing through the bedding plane. On the high wall, vibration propagates toward the dip direction of the bedding plane, whereas on the low wall, vibration propagates toward the opposite direction.

The ground vibration readings obtained from nineteen blasting operations at Adaro, where up to five vibration monitors were used, consist of 21 readings from the side wall, 28 readings from the high wall, and 21 readings from the low wall

The primary explosive used was ammonium nitrate – fuel oil

Table 1
PPV predictors using the scaling law method.

Name	Equation
Langefors–Kihlstrom[7]	$PPV = k[W^{1/2}/R^{1/3}]^n$
Ambressys–Hendron[8]	$PPV = k[W^{1/3}/R]^n$
Nicholls – USBM[9]	$PPV = k[W^{1/2}/R]^n$
Bureau of Indian Standard[10]	$PPV = k[W/R^{2/3}]^n$

(ANFO). Two types of blasting hole with diameters of 200 mm and 135 mm were used, resulting in blasting patterns of 7 m burden with 8 m spacing and 5.5 m burden with 6.5 m spacing, respectively. The typical depths of blasting holes were 8 m and 6 m for diameters of 200 mm and 135 mm, respectively. In-hole delay detonators were 500 ms. Initiation pattern was delayed on surface by NONEL 100 ms and 25 ms. An example of the initiation pattern is shown in Fig. 1a. The initiation pattern was then used to calculate the amount of explosive per delay to be that which detonates within any given 8 ms period of time as proposed by Duvall.[12] According to Cunningham,[13] the in-hole detonator of 500 ms has a coefficient of variation (CoV) of 0.92%. This value of CoV would result standard deviation of approximately 4.6 ms. For shorter delay of surface detonator of 25 ms, the CoV would increase to 2.64% resulting standard deviation of approximately 0.65 ms. The system error of initiation time or delay overlap has been calculated that standard deviation was approximately 6.5 ms. This value was lower than the time window of 8 ms to quantify the amount of explosive per delay in this study.

2.2. Kaltim Prima coal

KPC's operation is located in Sangatta, about 310 km north of Balikpapan, the largest regional city of East Kalimantan, Indonesia. In 2012, KPC's total coal production reached 41 million tonnes coal.[14] Major coal seams have average thickness of approximately 0.5–15 m and dip of 10–40°. The intervening rocks consist of sandstone, siltstone and mudstone.

KPC is also an open pit operation, in which the overburden is excavated by drill-and-blast method. Explosive charges, spacing,

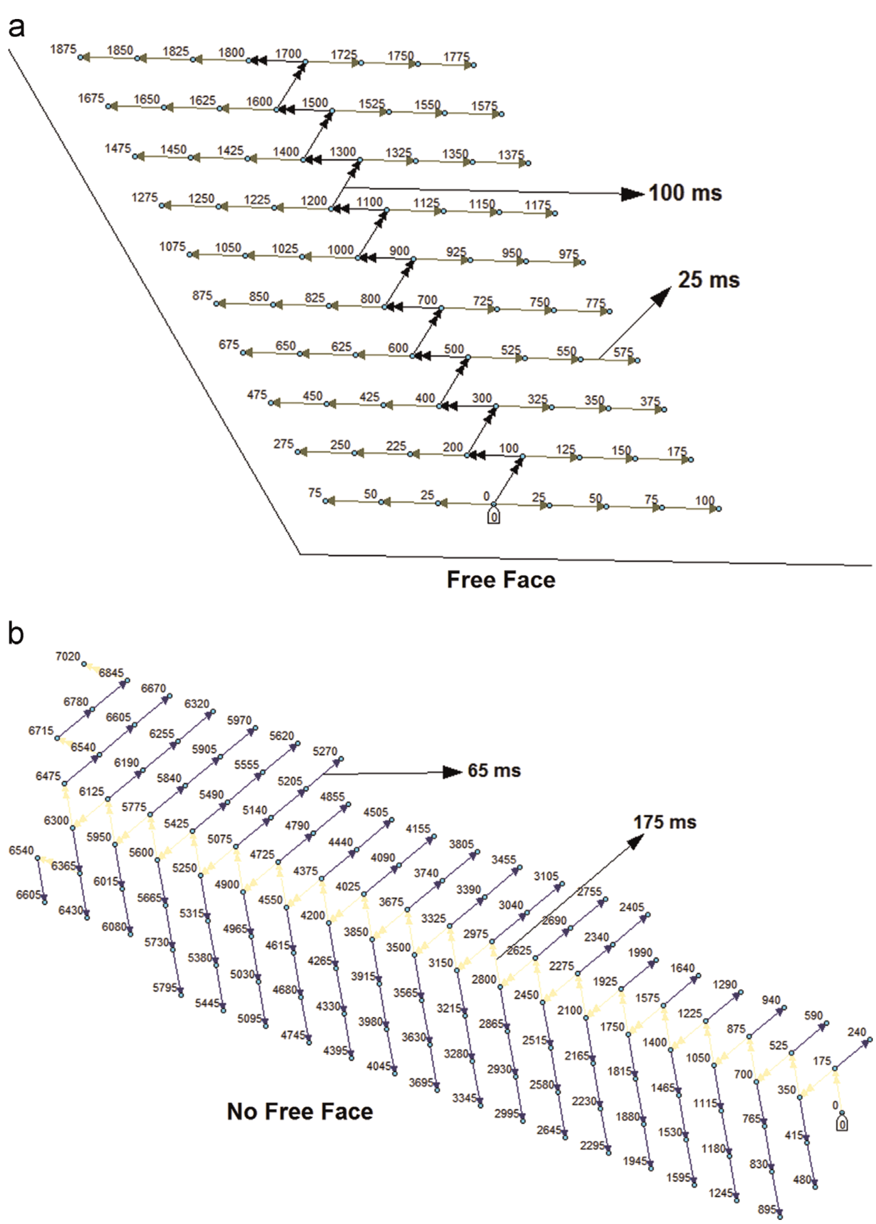

Fig. 1. Example of blasting pattern at (a) Adaro Indonesia and (b) Kaltim Prima Coal.