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APPROACH TO EXTRACTING THIN COAL SEAMS

The Mae Moh basin is located in the Mae Moh District of Lampang Province, which is about 26 km east of Lampang City. The basin floor is about 320–340 m above mean sea level. The Mae Moh basin consists of three formations, namely the Huai King, Na Khaem, and Huai Luang formations, in ascending order. Their total thickness is nearly 1,000 m. The Na Khaem formation is a coal measure comprising three main coal zones, *Q*, *K*, and *J*. This study introduces preliminary approaches to determining minimum thickness suitable for extracting thin coal seams meeting coal quality requirements or maximum allowable thickness of diluting partings requirements. The approach considers heating value as the main parameter to be determined and considered in different scenarios of losses and dilution. The study findings indicate that high-quality coal-bearing diluting rock partings, such as BK and BK3, can be excavated with K3 coal seam, and the allowable diluting parting thickness ranges 1.68–5.3 m at the required heating value of 2,800 kcal/kg. These diluting parting thicknesses can constitute up to 20–50 % of excavation thickness of K3 coal seam. Low-quality coal-bearing diluting rock partings, such as TK1, TQ, and BQ4, cannot be excavated with *K* and *Q* coal seams at all. Coal-bearing partings should have heating value more than 1,000 kcal/kg for having potential to be excavated with coal seams.

Keywords: : coal, thin coal seam, mining, losses, dilution.

1. INTRODUCTION

The Mae Moh basin is located in the Mae Moh District of Lampang Province, which is about 26 km east of Lampang City (Fig. 1). The basin floor is about 320-340 m above mean sea level. The Mae Moh basin consists of three formations, namely the Huai King, Na Khaem, and Huai Luang formations, in ascending order. Their total thickness is nearly 1,000 m. The Na Khaem formation is a coal measure comprising three members, namely, Member III, Member II, and Member I, in ascending order. Member III, or so-called underburden, is greenish gray to gray mudstone with a thin coal seam, named R coal zone. Member II is composed of two main coal zones, which are Q coal zone in the lowermost part and K coal zone in the uppermost part, with intercalated mudstone bed. Member I is thick overburden consisting of mudstone with a series of coal seams named J coal zone [1]. The J coal zone is presented by intercalation of mudstone and six main coal seams (Fig. 2).

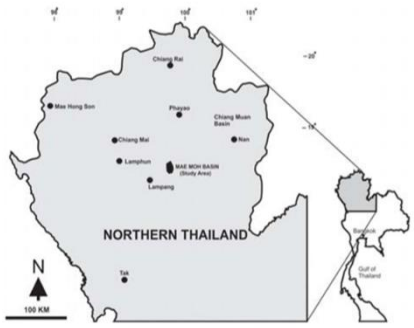
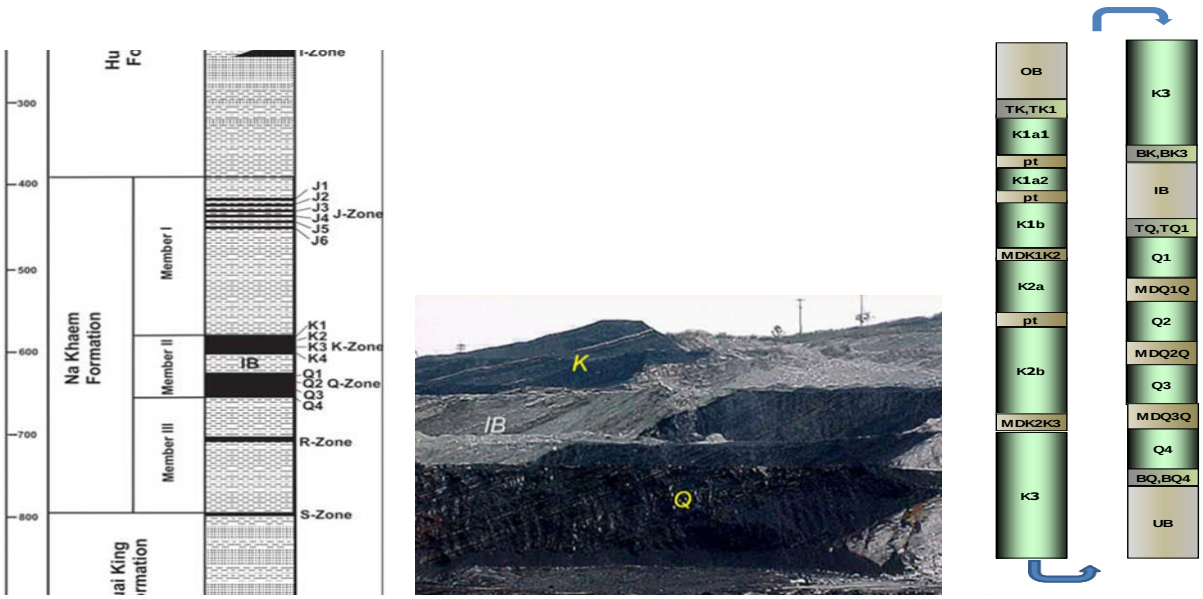


Fig. 1. Map of northern Thailand showing location of the Mae Moh basin with respect to locations of some provincial cities (After Wickanet Songthama, et. al. 2005)

Enlarged stratigraphic column of coal seams K and Q (Fig. 2, *b*) shows many partings (MD) within the coal seams. The boundary layers between coal seams and overburden (OB) or underburden (UB) are labeled as T and B (meaning top and bottom, respectively). For example, TK indicates the sublayer overlaying K coal seam. The parting/boundary layer thicknesses are important in mining. Some of them are extracted with coal, whereas other ones are not extracted.



a *b*

Fig. 2. Schematic lithostratigraphic column of Na Khaem Formation (a – After Wickanet Songthama, et.al. 2005, b – modified by authors)

This study offers approaches to determining minimum allowable coal seam thickness providing compliance with predetermined coal quality requirements. The approach considers heating value as the main parameter for determining the minimum coal seam thickness for different scenarios on losses and dilution.

2. THEORY

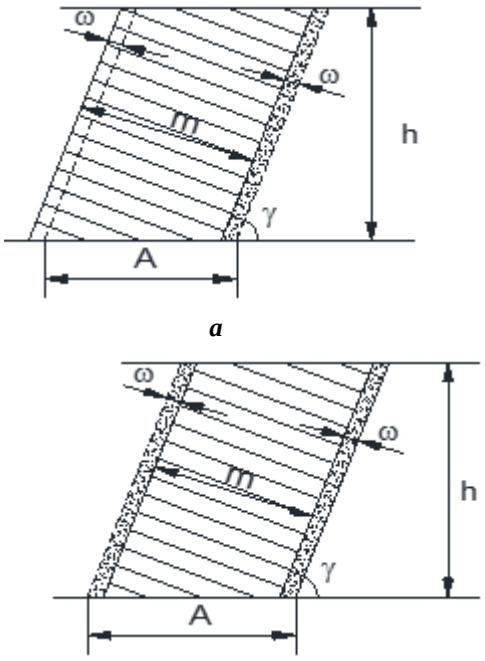
There are many methods to estimate the minimum allowable coal seam thickness to be extracted, such as heating value limit, economic limit, and selective ability of excavating equipment [2–8]. This study proposes the approaches to determining the minimum allowable coal seam thickness in accordance with heating value allowance.

When, at bench (sub bench) height (h), thickness of recoverable coal (m) and dip angle of coal seam (γ) are suitable for selective excavation, two approaches for estimating selective extraction could be presented:

a – Allowable losses at the roof of coal seam and dilution at the floor of coal seam (Fig. 3, a);

b – Allowable dilution at both boundaries of coal seam, at floor and roof, with no coal losses (Fig. 3, *b*).

In both approaches, it is assumed that the losses ("lost thickness" of coal seam) and diluting layers, represented by symbol ω, are equal to each other in thickness (m).



a

b

Fig. 3. Basic selective mining approaches for thin coal seams

The analysis results are derived from the equivalent heating values by using scattering functions [9].

2.1. Determination of the minimum allowable thickness of a coal seam to be extracted with adopting losses allowance at the roof and dilution allowance at the floor of coal seam.

Excavated raw coal weight is determined by:

$$W_m = \left[(m-\omega)\gamma_{coal} + \omega\gamma_{soil}\right]\frac{h}{\sin\gamma}, \text{ tons.} \quad (1)$$

Weight of coal in the raw coal is determined by:

$$W_{coal} = \left[(m-\omega)\gamma_{coal}\right]\frac{h}{\sin\gamma}, \text{ tons.} \quad (2)$$

Weight of coal-bearing soil (rock) in the raw coal is determined by:

$$W_{soil} = \left[\omega\gamma_{soil}\right]\frac{h}{\sin\gamma}, \text{ tons}, \quad (3)$$

where m is true thickness of coal, meters, γ_{coal},γ_{soil} are coal and soil (rock) densities, t/m^3, respectively. Soil in this study means any coal-bearing rock layers adjacent to coal seam.

Heating value, H, is added to equation. H_{Mcoal} is heating value of raw coal, kcal/kg. H_{coal} is heating value of coal, kcal/kg. H_{soil} is heating value of coal-bearing soil (rock), kcal/kg.

$$W_m H_{M_{coal}} = W_{coal}H_{coal} + W_{soil}H_{soil};$$

$$H_{M_{coal}} = \frac{W_{coal}H_{coal} + W_{soil}H_{soill}}{W_{coal} + W_{soil}}; \quad (4)$$

$$H_{M_{coal}} = \frac{\left[(m-\omega)\gamma_{coal}H_{coal}\right] + \left[\omega\gamma_{soil}H_{soil}\right]}{(m-\omega)\gamma_{coal} + \omega\gamma_{soil}}.$$

If acceptable heating value of raw coal H_{Mcoal} is equal to the required figure for a coal-fire power plant, $H_{required}$, H_{Mcoal} can be replaced with $H_{required}$ in equation (4).

After rearranging the equation, m, the minimum allowable coal seam thickness, can be determined:

$$m = \omega\left[1 + \frac{\gamma_{soil}}{\gamma_{coal}}\frac{\left(H_{soil} - H_{required}\right)}{\left(H_{required} - H_{coal}\right)}\right], \text{m.} \quad (5)$$

On the other hand, maximum allowable thickness of diluting layer ω can be determined as well if the allowable coal thickness m is known.

$$\omega = m/\left[1 + \frac{\gamma_{soil}}{\gamma_{coal}}\frac{\left(H_{soil} - H_{required}\right)}{\left(H_{required} - H_{coal}\right)}\right], \text{m.} \quad (6)$$

2.2. Determination of the minimum coal seam thickness to be mined with adopting dilution at both the floor and the roof of a coal seam.

The above-described method is applied to this scenario and allows determining H_{Mcoal}:

$$H_{M_{coal}} = \frac{m\gamma_{coal}H_{coal} + 2\omega\gamma_{soil}H_{soil}}{\omega\gamma_{coal} + 2\omega\gamma_{soil}}, \text{ kcal/kg} \quad (7)$$

And after rearrangement,

$$m = 2\omega\frac{\gamma_{soil}}{\gamma_{coal}}\frac{\left(H_{soil} - H_{required}\right)}{\left(H_{required} - H_{coal}\right)}; \quad (8)$$

$$\omega = m/\left[2\frac{\gamma_{soil}}{\gamma_{coal}}\frac{\left(H_{soil} - H_{required}\right)}{\left(H_{required} - H_{coal}\right)}\right]. \quad (9)$$

2.3 Determination of the minimum allowable coal seam thickness to be mined at adopting dilution at the floor or roof of a coal seam (Fig. 4).

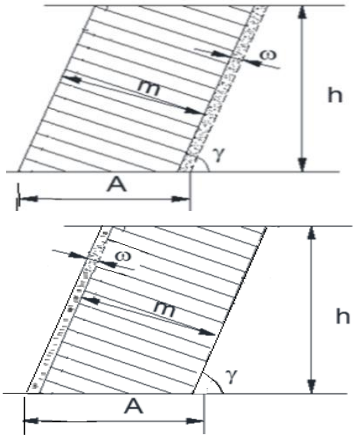


Fig. 4. Alternative selective mining approaches for coal seams

In this scenario, the minimum allowable coal seam thickness can be determined as follows

$$m = \omega\frac{\gamma_{soil}}{\gamma_{coal}}\frac{\left(H_{soil} - H_{required}\right)}{\left(H_{required} - H_{coal}\right)}; \quad (10)$$

$$\omega = m/\left[\frac{\gamma_{soil}}{\gamma_{coal}}\frac{\left(H_{soil} - H_{required}\right)}{\left(H_{required} - H_{coal}\right)}\right]. \quad (11)$$

3. DATA

The characteristics, such as heating value, density, ash content (%) of productive coal seams *K*, *Q*, and other seams/layers are summarized in Table 1. The data represent some working areas and are averaged values.

Table 1

Properties of seams/layers of A1 and A2 areas

Area	Seam Name	Average Heating Value, *H* (kcal/kg)	Ash content (%)	Density (ton/m^3)
	TK1	435.7	52.2	1.95*
	PT	379.1	49.6	1.81
A1, A2	*K1*	*3,070*	*12.3*	1.62
	K2	*2,854*	*16.6*	
	K3	*3,181*	*9.8*	
	BK	2,274	26.9	2.19
	BK3	1,130	44	2.19
	TQ	268	52.8	2.06**
	Q1	*2,757*	*16*	1.5
	Q2	*2,600*	*20.7*	
	Q3	*1,782*	*34.2*	
	Q4	*2,702*	*18.5*	
	BQ4	280	55.2	1.95*

* *using gray mudstone density in overlaying and underlying (OB and UB) layers*
** *using green zone density in interlayers (IB) [3]*

4. RESULTS

Based on the schematic lithostratigraphic column, including members I, II and III of the Na Khaem Formation, this study focuses on the following coal seam boundaries: (a) TK1 and K1 seam, (b1) BK and K3, (b2) BK3 and K3, (c) TQ and Q1, and (d) BQ4 and Q4. Equations 10 and 11 can be applied to these scenarios.

From preliminary requirements of Mae Moh mine [10], the thickness of diluting soil (rock) layer is allowed to be up to 0.30 meters (ω), and heating value is adopted at 2,800 kcal/kg. Using these conditions and data from Table 1, the minimum coal seam thickness (*m*) can be determined using equation 10, as shown in the Table 2.

Table 2

Minimum allowable thicknesses of coal seams K1, K3, Q1, and Q44

	m (meters)			
ω = 0.30 (meters)	K1	K3	Q1	Q4
TK1	3.16			
BK		0.56		
BK3		1.78		
TQ			N/A	
BQ4				N/A

N/A indicates that heating value of TQ and BQ4 are too low for these layers to be excavated with Q1 and Q4 coal seams in order to meet the requirement of the minimum heating value of 2,800 kcal/kg with the diluting layer of 0.30 m thick.

In addition, thicknesses of coal seams K and Q range 10–35 meters being much more than the minimum thickness indicated in the Table 2.

In addition, the allowable diluting parting thickness can be estimated to meet any heating value requirement, with the assumption of excavation with K and Q coal seams being 10 m thick. The estimation results (using equation 11) are shown in Table 3.

Table 3

Allowable thickness of diluting partings when excavating with coal seam 10 m thick at any heating value requirements

	ω (meters)			
Heating value required (kcal/kg)	2,800	2,900	3,000	3,100
TK1	0.94	0.57	0.22	N/A
BK	5.3	3.32	1.84	0.72
BK3	1.68	1.17	0.71	0.30
TQ	N/A	N/A	N/A	N/A
BQ4	N/A	N/A	N/A	N/A

N/A indicates that heating value of TQ and BQ4 (and TK1 at 3,100 kcal/kg) are too low to be excavated with Q1 and Q4 coal seams for meeting any heating value requirements with the assumption of excavation of these layers with coal seams 10 m thick.

As seen from Table 3, the allowable thickness of diluting parting decreases at higher required heating value. A simple rule of thumb to determine appropriate diluting parting thickness, for example, can be up to 10 % of TK1 (at 2,800 kcal/kg) at any extraction thickness of K1 coal seam or up to 50 % of BK (at 2,800 kcal/kg) at any extraction thickness of K3 coal seam.

4. SUMMARY

This study presents approaches to determining minimum allowable coal seam thickness and allowable diluting parting/layer thicknesses to be excavated at any losses and dilution scenarios. The study is based on using schematic lithostratigraphic column of the Na Khaem Formation from Mae Moh mine, Thailand. Geological and properties data from the mine areas are provided and applied to the considered scenarios using and scattering equation. The study focuses on several boundaries between coal-bearing rock layers and coal seams: (a) TK1 and K1 seam, (b1) BK and K3, (b2) BK3 and K3, (c) TQ and Q1, and (d) BQ4 and Q4. The boundary conditions vary depending on geological structure of Mae Moh basin. Based on preliminary requirements, the study findings indicate that high-quality coal-bearing diluting rock partings, such as BK and BK3, can be excavated with K3 coal seam, and allowable diluting parting thickness ranges 1.68–5.3 m at the required heating value of 2,800 kcal/kg. These diluting parting thicknesses can constitute up to 20-50 % of excavation thickness of K3 coal seam. Low-quality coal-bearing diluting rock partings, such as TK1, TQ, and BQ4, cannot be excavated with K and Q coal seams at all. Coal-bearing partings should have heating value more than 1,000 kcal/kg for having potential to be excavated with coal seams. Finally, these approaches can only be used as a preliminary guideline to determine allowable extracting thickness of both coal seams and coal-bearing partings. Many parameters should be considered for making final decision on allowable thickness of diluting partings.

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Title:	**APPROACH TO EXTRACTING THIN COAL SEAMS**
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