APPROPRIATION OF RECOVERING THIN COAL SEAMS

The Mae Moh basin is situated 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. The total thickness is nearly 1000 m in ascending order. The Na Khaem formation is a coal measure comprising three main coal zones, Q, K, and J. This study introduces preliminary approaches to determine minimum thickness to excavate thin coal seams within coal quality requirements or maximum dilution thickness acceptance. The approach considers heating value as a main parameter to determine under different scenarios of loss and dilution. The results indicate the high quality of coal-bearing soil seams, such as BK and BK3 can be excavated with K3 and acceptable dilution thickness is between 1.68–5.3 m at 2800 kcal/kg of heating value. These dilution thickness can be converted to 20–50% at any excavated thickness of K3 coal seam. Low quality of coal-bearing soil seams, such as TK1, TQ and BQ4, cannot be excavated with any K and Q coal seams. Coal-bearing parting layer should have heating value more than 1,000 kcal/kg to possibly be excavated with coal seams.

Keywords: Coal, Thin Coal Seam, Mining, Loss, Dilution

1. INTRODUCTION

The Mae Moh basin is situated 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. The total thickness is nearly 1000 m in ascending order. The Na Khaem formation is a coal measure comprising three members as Member III, Member II, and Member I, in ascending order. The Member III, or the so-called underburden, is a greenish gray to gray claystone with a thin layer of coal, named the R coal zone. The Member II is composed of two main coal zones, which are the Q coal zone in the lowermost part and the K coal zone in the uppermost part, and are intercalated by an interburden of claystone. The Member I is a thick overburden consisting of claystone with a series of coal layers named the J coal zone [1]. The J coal zone is an intercalation between claystone and six main coal layers (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 Songtha ma, et. al. 2005)

An enlarged stratigraphic of coal seam K and Q (Fig. 2, b) indicates many mid band layers (MD) within the coal seams. The boundary layers between coal seams and overburden (OB) or underburden (UB) are specified as letter T and B means top and bottom, respectively. For example, TK1, TQ and BK4, cannot be excavated with any K and Q coal seams. Coal-bearing parting layer should have heating value more than 1,000 kcal/kg to possibly be excavated with coal seams.

Some are extracted with the coal, some are not.
This study introduces approaches to determine minimum thickness to excavate thin coal seams within predetermined coal quality requirements. The approach considers heating value as a main parameter to determine the minimum thickness of coal seam under different scenarios of loss and dilution.

2. THEORY

There are many methods to calculate the minimum thickness of coal seam which is allowed to be mined, such as heating value limit, economic limit, and selective ability of excavating equipment [2–8]. This study proposes the approaches to determine the minimum thickness of coal seam that is allowed to be mined in accordance with heating value allowance.

When bench height (sub bench) \( h \) has been suitable for selective excavating operation such as the thickness of recoverable coal \( m \), dip angle of coal seam \( \gamma \), two approaches for selective mining could be shown:

\( a \) – Acceptable loss at the roof of coal seam and dilution at the floor of coal seam (Fig. 3, \( a \));

\( b \) – Acceptable dilution at both boundaries of coal seam, floor and roof without coal loss (Fig. 3, \( b \)).

In both the two approaches, it is assumed that the loss or dilution layers are equal each other, represented by symbol \( \omega \) (m).
The analysis results are derived from the equivalent heating values by using scattering functions [9].

2.1. Determination of the minimum thickness of coal seam could be mined with acceptance of loss allowance at the roof and dilution allowance at the floor of a coal seam.

Excavated raw coal weight is determined by:

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

Weight of coal in the raw coal is determined by:

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

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

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

where \( m \) is true thickness of coal, meters, \( \gamma_{coal}, \gamma_{soil} \) are coal and soil density, \( \text{t/m}^2 \). Soil in this study means any coal-bearing soil layers that is adjacent main coal seam.

The heating value, \( H \), are added into equation. \( H_{M,coal} \) is heating value of raw coal, kcal/kg. \( H_{coal} \) is heating value of coal, kcal/kg. And \( H_{soil} \) is heating value of coal-bearing soil, kcal/kg.

\[ W_m H_{M,coal} = W_{coal} H_{coal} + W_{soil} H_{soil}; \]

\[ H_{M,coal} = \frac{W_{coal} H_{coal} + W_{soil} H_{soil}}{W_{coal} + W_{soil}}; \] (4)

\[ H_{M,coal} = \left[ (m - \omega) \gamma_{coal} H_{coal} \right] + [\omega \gamma_{soil} H_{soil}]. \]

If acceptable heating value of raw coal; \( H_{M,coal} \), is equal to heating value requirement; \( H_{required} \), for coal fire power plant. \( H_{M,coal} \) will be replaced with \( H_{required} \) in equation (4).

After rearranging the equation, \( m \) or minimum thickness of coal seam can be determined:

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

On the other hand, maximum layer of \( \omega \) can be determined as well if available coal thickness \( m \) is known.

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

2.2. Determination of the minimum thickness of coal seam could be mined with dilution acceptance at both the floor and the roof of coal seam.

The above-mentioned method is applied to this scenario and \( H_{M,coal} \) can be determined.

\[ H_{M,coal} = m \left[ \frac{\gamma_{soil} (H_{soil} - H_{required})}{\gamma_{coal} (H_{required} - H_{coal})} \right], \text{kcal/kg} \] (7)

And after rearrangement,

\[ m = \frac{2 \gamma_{soil} (H_{soil} - H_{required})}{\gamma_{coal} (H_{required} - H_{coal})}; \] (8)

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

2.3 Determination of the minimum thickness of coal seam could be mined with dilution acceptance at floor or roof of the coal seam (Fig. 4).

\[ \omega = m \left[ \frac{\gamma_{soil} (H_{soil} - H_{required})}{\gamma_{coal} (H_{required} - H_{coal})} \right], \text{m.} \] (10)

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

3. DATA

The characteristics, such as heating value, density, percentage of ash, of productive coal seam \( K, Q \), and other layers are summarized in the Table 1. The data is selected from some of working areas and averaged values.

**Fig. 4. Alternative selective mining approaches for coal seams**
4. RESULTS

From the schematic lithostratigraphic member I, II and III units of the Na Khaem Formation, this study focuses on four 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. Equation 10 and 11 can be applied to these scenarios.

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

In addition, the geological thickness of coal seam K and Q vary between 10-35 meters that have thickness much more than minimum thickness indicated in the Table 2.

On the other hand, the allowable dilution thickness can be determined to meet any heating value requirement, with the assumption of excavation with K and Q coal seam 10 meters. By using equation 11, the results are displayed in Tab. 3.

From Tab. 3, the allowable thickness of dilution layer decreases at higher heating value requirements. A simple rule of thumb to determine appropriate dilution thickness, for example, can be up to 10 % of TK1 (at 2,800 kcal/kg) at any excavated thickness of K1 coal seam or up to 50 % of BK (at 2,800 kcal/kg) at any excavated thickness of K3 coal seam.

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

**Table 1**

Properties of geological seams of A1 and A2 areas

<table>
<thead>
<tr>
<th>Area</th>
<th>Seam Name</th>
<th>Average Heating Value, ( H ) (kcal/kg)</th>
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</table>

**Table 2**

Minimum thickness of coal seam K1, K3, Q1 and Q4

<table>
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<tr>
<th>Area</th>
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<th>Average Ash (%)</th>
<th>Density (ton/m(^3))</th>
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<td>280</td>
<td>55.2</td>
<td>1.95</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3**

Allowable thickness of dilution layers when excavated with 10-meter thickness coal seam at any heating value requirement

<table>
<thead>
<tr>
<th>Heating value required (kcal/kg)</th>
<th>( \omega ) (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,800</td>
<td>0.94</td>
</tr>
<tr>
<td>2,900</td>
<td>0.57</td>
</tr>
<tr>
<td>3,000</td>
<td>0.22</td>
</tr>
<tr>
<td>3,100</td>
<td>N/A</td>
</tr>
<tr>
<td>TK1</td>
<td></td>
</tr>
<tr>
<td>BK</td>
<td>5.3</td>
</tr>
<tr>
<td>BK3</td>
<td>3.32</td>
</tr>
<tr>
<td>TQ</td>
<td>1.84</td>
</tr>
<tr>
<td>Q1</td>
<td>0.71</td>
</tr>
<tr>
<td>BQ4</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Table 4**

Using gray claystone density in over and under burden (OB and UB) layers

**Table 4**

Using green zone density in interburden (IB) layers [3]

**Table 4**

Using gray claystone density in over and under burden (OB and UB) layers

**Table 4**

Using green zone density in interburden (IB) layers [3]
4. SUMMARY

This student introduces approaches to determine either minimum thickness of coal seam or allowable dilution thickness to be excavated with any loss and dilution scenarios. A study case is raised using schematic lithostratigraphic units of the Na Khaem Formation from Mae Moh mine, Thailand. Geological and properties data from parts of mine areas are provided and applied to an appropriate scenario and scattering equation. The study focuses on four boundaries of coal-bearing soil and coal seam: (a) TK1 and K1 seam (b1) BK and K3 (b2) BK3 and K3 (c) TQ and Q1, and (d) BQ4 and Q4. These conditions of boundaries are very depending on geological structure of Mae Moh basin. From preliminary requirements, the results indicate that the high quality of coal-bearing soil seams, such as BK and BK3 can be excavated with K3 and acceptable dilution thickness is between 1.68-5.3 meters at 2,800 kcal/kg of heating value. These dilution thickness can be converted to 20–50% at any excavated thickness of K3 coal seam. Low quality of coal-bearing soil seams, such as TK1, TQ and BQ4, should not and cannot be excavated with any K and Q coal seams. Coal-bearing parting layer should have heating value more than 1,000 kcal.kg to possibly be excavated with coal seam. Finally, these approaches can only be used as a preliminary guideline to determine appropriate thickness of both coal and coal-bearing soil seams. Many parameters should be considered for making final acceptable dilution thickness.

ACKNOWLEDGEMENTS

This study cannot be done without data and supports from Mae Moh mine, the Electricity Generation Authority of Thailand (EGAT). The authors are also grateful to all geologists and engineers from geotechnical and mine planning sections for their kind assistances and supports.

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### Title:
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