Crushing
Optimizing the Process

QUARRY ACADEMY

Improving Processes. Instilling Expertise.
SUSTAINABILITY

PROFITABILITY

PRODUCTIVITY

BREAK ROCK
Chemical Crushing

MOVE ROCK
Load and Haul

SIZE ROCK
Mechanical Crushing and Screening

PLANNING AND METRICS

SAFETY CULTURE
Optimizing the Process

- Methods to combine and simulate technical and economic performance
- Optimum crushing plant performance is difficult to achieve due to the process characteristics. Different compared to all other industrial processes.
- Optimizing method for best performance
- Partly implemented in PlantDesigner 10
Crushing Plant Optimization

• Point of interest
  – Crushing stage
  – Crushing plant
  – Quarry Process

• Today:
  – Optimize the feed
  – Optimize the process
MinBaS II
Optimized blasting

Field Study in Långåsen, Arlanda

- Full scale testing. Four blasts blasted during 2008
- Based on the final report and my own observations
- All data and costs shown are estimates based on publically available data
The Study

• Comparisons between the cost and earnings for different blasting strategies.
• Conclusions and recommendations
The Quarry
Långåsen, Arlanda

- Operated by NCC Roads
- Capacity 300-400 tph
- Aggregates and Asphalt Production
- Contractor for transportation of blasted material to primary crusher
- Contractor owns and operates the C&S plant

Aphalt plat
C&S plant

Test area 4 Blasts
Blast 0 resting.
# Blasted Material Test plan

<table>
<thead>
<tr>
<th>Blast</th>
<th>None Electric</th>
<th>None Electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast 1</td>
<td>None Electric</td>
<td>None Electric</td>
</tr>
<tr>
<td></td>
<td>1.35 lb/yd³</td>
<td>1.85 lb/yd³</td>
</tr>
<tr>
<td>Blast 2</td>
<td>None Electric</td>
<td>None Electric</td>
</tr>
<tr>
<td></td>
<td>1.85 lb/yd³</td>
<td>1.35 lb/yd³</td>
</tr>
<tr>
<td>Blast 3</td>
<td>Electronic Blasting System</td>
<td>1.35 lb/yd³ 10 ms between holes</td>
</tr>
<tr>
<td>Blast 4</td>
<td>Electronic Blasting System</td>
<td>1.35 lb/yd³ 5 ms between holes</td>
</tr>
</tbody>
</table>
Blasting result

Measuring the Particle Size Distribution
## Blasting result
### Cost analysis

<table>
<thead>
<tr>
<th></th>
<th>Nonel norm. q [$/ton*]</th>
<th>Nonel high q [$/ton*]</th>
<th>EPD norm. q [$/ton*]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling and Blasting</td>
<td>0.90</td>
<td>1.23</td>
<td>0.97</td>
</tr>
<tr>
<td>Added cost for detonators</td>
<td>0,00</td>
<td>0,00</td>
<td>0.30</td>
</tr>
<tr>
<td>Bolder Management</td>
<td>0.30</td>
<td>0.15</td>
<td>0.22</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>1.20</strong></td>
<td><strong>1.38</strong></td>
<td><strong>1.49</strong></td>
</tr>
</tbody>
</table>

*Estimates based on publicly available data*
Loading and Hauling Conditions and Measurements

• Loading and Hauling to primary crusher
  – Wheel loader carries the material from the muck pile to the crusher

• Conducted studies
  – Measurement of wheel loaded loading times
  – Measurement of loaded material [tph]
  – Manual timing during several days
# Loading and Hauling Cost analysis

<table>
<thead>
<tr>
<th></th>
<th>Nonel norm. q</th>
<th>Nonel high q</th>
<th>EPD norm. q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contractor [$/h*]</td>
<td>448</td>
<td>448</td>
<td>448</td>
</tr>
<tr>
<td>Loading Capacity [tph]</td>
<td>298</td>
<td>316</td>
<td>313</td>
</tr>
<tr>
<td>Cost [$/ton]</td>
<td>1.50</td>
<td>1.42</td>
<td>1.43</td>
</tr>
<tr>
<td>Sum incl Drilling and Blasting [$/ton]</td>
<td>1.20+1.50=</td>
<td>1.38+1.42=</td>
<td>1.49+1.43=</td>
</tr>
<tr>
<td></td>
<td>=2.70</td>
<td>=2.80</td>
<td>=2.92</td>
</tr>
</tbody>
</table>

*Estimates based on publicly available data*
Crushing and Screening
Plant Setup and Conditions for the Study

0-3.5” (0-90 mm)  
+3.5” (+90 mm)
Crushing and Screening
Performed Measurements
## Crushing and Screening Cost analysis

<table>
<thead>
<tr>
<th></th>
<th>Nonel norm. q</th>
<th>Nonel high q</th>
<th>EPD norm. q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Draw (kWh/ton)</td>
<td>0.3</td>
<td>0.25</td>
<td>0.35</td>
</tr>
<tr>
<td>Energy Cost (0.30 $/kWh)*</td>
<td>0.09</td>
<td>0.07</td>
<td>0.10</td>
</tr>
<tr>
<td>Fixed Cost [$/h]</td>
<td>746</td>
<td>746</td>
<td>746</td>
</tr>
<tr>
<td></td>
<td>2.41</td>
<td>2.29</td>
<td>2.28</td>
</tr>
<tr>
<td>Cost [$/ton]</td>
<td>2.50</td>
<td>2.36</td>
<td>2.38</td>
</tr>
<tr>
<td>Sum incl D&amp;B och L&amp;H [$/ton]</td>
<td>1.20+1.50+2.50=</td>
<td>1.38+1.42+2.36=</td>
<td>1.49+1.43+2.38=</td>
</tr>
<tr>
<td></td>
<td>= 5.20</td>
<td>= 5.16</td>
<td>= 5.30</td>
</tr>
</tbody>
</table>

*Estimates based on publicly available data*
# Production

**Total cost $/h**

<table>
<thead>
<tr>
<th>Nonel</th>
<th>Nonel</th>
<th>EPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>norm. q</td>
<td>high q</td>
<td>norm. q</td>
</tr>
<tr>
<td>Production rate [tph]</td>
<td>298</td>
<td>316</td>
</tr>
<tr>
<td>Cost [$/h]</td>
<td>1600</td>
<td>1676</td>
</tr>
</tbody>
</table>

Distribution between 0-3.5” and +3.5” is partly controlled by the blasting result.
## Procution Product Price

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0-90</td>
<td>11.94</td>
<td>1 (Prim.)</td>
<td>11.94</td>
</tr>
<tr>
<td>0-4</td>
<td>19.25</td>
<td>3-4</td>
<td>21.19</td>
</tr>
<tr>
<td>4-8</td>
<td>20.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-11</td>
<td>23.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-16</td>
<td>22.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16-32</td>
<td>20.15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Estimates based on publicly available data*
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<th>Nonel high q</th>
<th>EPD normalt q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production [tph]</td>
<td>298</td>
<td>316</td>
<td>313</td>
</tr>
<tr>
<td>Production 0-3.5” [tph]</td>
<td>186</td>
<td>206</td>
<td>189</td>
</tr>
<tr>
<td>Price 0-3.5” $/ton*</td>
<td>11.94</td>
<td>11.94</td>
<td>11.94</td>
</tr>
<tr>
<td>Production +3.5” [tph]</td>
<td>112</td>
<td>110</td>
<td>124</td>
</tr>
<tr>
<td>Revenue $/h</td>
<td>4595</td>
<td>4791</td>
<td>4885</td>
</tr>
</tbody>
</table>

*Estimates based on publicly available data*
### Production Cost and Revenue*

<table>
<thead>
<tr>
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<th>EPD norm. q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production rate [tph]</td>
<td>298</td>
<td>316</td>
<td>313</td>
</tr>
<tr>
<td>Cost [$/h]</td>
<td>1343</td>
<td>1412</td>
<td>1425</td>
</tr>
</tbody>
</table>

*Based on publicly available data

Minimizing cost does not necessarily profit

Distribution between 0-3.5” and +3.5” is partly controlled by the blasting result
Conclusions

• From the tested blasting alternative Electronic Blasting System is the most beneficial.
• Extensive investigations and analysis are necessary in order to determine the optimal solution. Many areas are effected by the blasting result.
  – Drilling and Blasting
  – Bolder Management
  – Loading and Hauling
  – Crushing and Screening
• Only studying the costs is not sufficient in order to optimize the process. Most expensive solution did also generate the most profit.
Conclusions – Guidance for previous processes

- Feed to the primary crusher matters more than just boulders
- The effect of different feed gradations (blast results) are difficult to detect without measuring actively.
- Communicate effects upwards in the process
What about Optimizing the Crushing and Screening Process?

- Optimizing a single crusher can be done manually as seen earlier
- Optimizing several crushers?
  - Combination of equipment setting
  - Production situation, what products are demanded and what are not?
Crushing plant optimization using TCO

Objective of project

• To optimize the crushing plant using computer optimization
• Use sampling to calibrate the computer model in order to increase model accuracy
• Optimize with the goal to maximize gross profit
Yield the most profitable production strategy and meet the market demand

Optimization cannot be done without including economics
Crushing plant optimization using TCO Calculation approach

- Included in cost the calculation
  - Raw material
  - Depreciation
  - Interest
  - Energy cost
  - Wear parts replacement
  - Service cost
  - By-product production
  - Personnel

- Income calculation
  - Sellable products
  - Product demand

- Other factors included that effects the gross profit
  - Availability
  - Utilization
Crushing plant optimization using TCO

Plant Challenges

What is the best trade-off between capacity and reduction?
Crushing plant optimization using TCO

Test plant

In normal production following CSS are utilized:

- **Secondary crusher** – CSS 44 mm 1.73”
- **Tertiary crusher** – CSS 16 mm 0.63”
- **Quaternary crusher** – CSS 13 mm 0.51”

**Products:**
- 0-2 mm
- 2-5 mm
- 5-8 mm
- 8-11 mm
- 11-16 mm
- 16-22 mm
- 0-0.9”
Crushing plant optimization using TCO

Test plan

Objectives for the first test session:

• Measure particle size distribution to calibrate the simulation model
• CSS at original settings
Crushing plant optimization using TCO Model Calibration
Crushing plant optimization using TCO

Running the TCO optimization module

The computer tool automatically finds the best solution using an optimization algorithm

The solution that yields the best profit:

- Secondary crusher – CSS 50 mm (44), 1.96” (1.73”)
- Tertiary crusher – CSS 20 mm (16) 0.78” (0.63”)
- Quaternary crusher – CSS 14 mm (13) 0.55” (0.51”)
Crushing plant optimization using TCO

Results

- Increased Capacity
- Reduced fines ratio
- Increased total production

Result: +11 % in Calculated Gross Profit
Crushing plant optimization using TCO
How can it be done?
Crushing plant optimization using TCO

Conclusion

- Optimization must be a combination of technical and economic analysis
- Computer optimization can improve productivity
- Model calibration increases accuracy
- Minimizing cost does not necessarily maximize profit
- Combined performance of different machines should be considered. Solves the trade-off between capacity and reduction
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