Structural and stability assessment for ex-pit dump toe locality optimisation: A case study

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BBUGS / BOHOGS Supplier’s day - Moranbah
Ukhaa Khudag coal mine, Mongolia
Project location
Project infrastructure

18 MW Power Station

15 Mtpa CHPP

Office and mess hall

Mine Workshops
Some key facts

- Multiple seams dipping generally 3° to 17° into highwall
- Flanks (endwalls) dipping 5° to 40° out of pit wall
- Terrace mining (truck and excavator)
- Mid volatile hard coking coal with thermal coal by-product
- Ex-pit waste dumping, at least for next 3 to 5 years
- Nameplate capacity of 15 Mtpa ROM coal to CHPP
- Life-of-Mine stripping ratio of 5.6:1
The challenge

Optimise the locality of the northern ex-pit waste dump on order to reduce dump truck round trip distances.

Earlier limit equilibrium analyses of cross-sections for pit walls below the dump indicated the potential to steepen the OSA by as much as 4° through buffer blasting the entire slope.

Insufficient geotechnical and geological data available to properly identify buffer blasting target zones.

The phreatic surface used is based on John Simmons’ work from the Bowen Basin (far wetter conditions)
The challenge in a nutshell

New “optimised” crest locality

Possible structural interp. with additional data

Potential gain

50m stand-off distance not assessed – remains constant

LOM structural interp.
Plan of action

Drill a series of six geotechnical boreholes sited to maximise data from the potential buffer blasted endwall area. Boreholes required to be oriented to enable structural and kinematic analyses.

Drill ten percussion holes adjacent to and on top of the waste dump to determine actual phreatic surface.

Review geological structure of the ground containing the final endwall slope beneath the waste dump.

Conduct kinematic and limit equilibrium analyses to design optimal OSA beneath the waste dump using the updated structural and phreatic surface data.
Modifications

No acoustic televiewer available in country. Changed to drilling oriented cored boreholes

60° inclined core boreholes, oriented by means of Ezy-Mark tool (Reflex). Relies on leaving a crayon impression and a pin profile of the bottom of the hole

Soft and friable coal and mudstone areas - too much fine and loose material at bottom of hole to obtain an impression. Oriented core data unavoidably biased to the stronger units

Inability to orient core in softer zones judged not to be a show stopper. Overall structural orientations expected to be similar in hard and softer rock
Modifications continued

Two oriented holes close to the dump toe intersected basement rock (dolerite and basalt) and “replacement” holes were drilled about 100 m further (South) from the dump toe.

Info on the basement contacts and structure was nevertheless very useful.
Oriented core drilling
Coring through the waste dump

Local exploration drilling contractor used for the dump hydrology holes. Did not have a percussion rig available so drilled the holes with a coring rig.

Core was not boxed or logged but simply laid out on the ground near the rig. Recovery of core not called for in the work order.

With an air drilled hole the expectation was that water level monitoring would track the gradual climb of water level back up to equilibrium. With water flushed coring the opposite was expected.
Waste dump core
Structural data collection

Oriented core holes logged and photographed by the site geotechnical team to CoreLog standard (ACARP 2015)

Individual defects identified and measured using CoreProfiler (CSIRO). Builds a composite photograph of the core column from core photographed in trays. From this, dip and dip direction are determined for each defect and plotted on stereonet. Data was then exported to Dips6.0 for further manipulation and assessment

CoreProfiler also produces RQD and fracture frequency data

CoreProfiler is still in development but was found to be a useful tool
CoreProfiler – core box photo

From this:
CoreProfiler work page example

To this:
Structural assessment

Structural data analysed in Dips6.0 as follows:

• All defects in all boreholes, then split per endwall sector (NEW2 and NEW4) and finally split into individual boreholes

• Each of the above were then sub-divided into:
  - All structure above the lowermost coal seam (BOC) and that below BOC – the latter being the key strata for endwall design
  - Bedding planes only split as above to determine structural trends in sedimentary rock

• Shears and possible shears analysed separately – insufficient numbers to analyse shears on a hole for hole basis.
Selected stereonet plots

All shears – all b/hs

All defects – all b/hs
<table>
<thead>
<tr>
<th>Description</th>
<th>Dip and Dip direction (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Set 1</td>
</tr>
<tr>
<td>All defects for all boreholes</td>
<td>13/207</td>
</tr>
<tr>
<td>All defects above BOC</td>
<td>11/211</td>
</tr>
<tr>
<td>All defects below BOC</td>
<td>13/204</td>
</tr>
<tr>
<td>Bedding planes only for all boreholes</td>
<td>13/208</td>
</tr>
<tr>
<td>Bedding planes only above BOC</td>
<td>14/213</td>
</tr>
<tr>
<td>Bedding planes only below BOC</td>
<td>12/203</td>
</tr>
<tr>
<td>All defects for basement rocks</td>
<td>11/214</td>
</tr>
<tr>
<td>Shears only for all boreholes (orientation low to medium confidence)</td>
<td>64/172</td>
</tr>
</tbody>
</table>
Kinematic assessment

Critical Surface Limits

• Batters
  - Final endwalls – 10%
  - Interim endwalls – 15%
  - Highwalls – 20%

• Overall slope angles
  - Below critical infrastructure – 5%
  - All others – 10%
Kinematic assessment

Planar and wedge sliding are the most likely, kinematically admissible, failure types

- Excluding the effect of shears:
  - Batters should not be formed steeper than 55° in NEW4 and 70° in NEW2
  - Overall slope angle (OSA) should not exceed 47°

- Taking shears into account:
  - Batter slope angle drops to 25°. OSA 23° for NEW2 and 30° for NEW4

- Assuming bedding shears will be buffer blasted:
  - Max batter angle 55° and OSA 27° to 34°
Selected stereonet plots

NEW2 batter scale wedge sliding

NEW2 batter scale planar sliding
## Kinematic analysis results summary

<table>
<thead>
<tr>
<th>Slope scale</th>
<th>Pit sector</th>
<th>Maximum slope dip angle and percentage of critical surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Planar sliding (° / %)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wedge sliding (CS Mod)* (° / %)</td>
</tr>
<tr>
<td>Batter (15% critical surfaces limit)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEW2</td>
<td></td>
<td>70/13.7</td>
</tr>
<tr>
<td>NEW4</td>
<td></td>
<td>55/14.9</td>
</tr>
<tr>
<td>NEW2 shears</td>
<td></td>
<td>28/14.3</td>
</tr>
<tr>
<td>NEW4 shears</td>
<td></td>
<td>59/7.1</td>
</tr>
<tr>
<td>OSA (10% critical surfaces limit)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEW2</td>
<td></td>
<td>49/9.8</td>
</tr>
<tr>
<td>NEW4</td>
<td></td>
<td>47/9.7</td>
</tr>
<tr>
<td>NEW2 shears</td>
<td></td>
<td>27/7.1</td>
</tr>
<tr>
<td>NEW4 shears</td>
<td></td>
<td>59/7.1</td>
</tr>
</tbody>
</table>

*The critical surface results for wedge sliding have a correction factor of 0.5 applied to better match site experience. This is referred to as the modified wedge sliding critical surface value (CS Mod.).

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Structural interpretation

General trend indicated steeper than originally modelled coal bearing strata along the northern boundary fault in 3 out of 4 cross-sections

The other cross-section indicated steeply dipping boundary fault cutting off the coal strata

A stronger and less disturbed conglomerate zone was identified below the BOC

Zone of steeply dipping sedimentary rocks assumed to extend along the southern face of the northern boundary fault. Based on previously exposed fault zones at UHG. Width variable
Dump toe and borehole locality
Structural interp. CS 20a
# Phreatic surface model

<table>
<thead>
<tr>
<th>Locality</th>
<th>Distance from toe (m)</th>
<th>Phreatic surface below original ground surface (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>240 m from dump toe (on pit side)</td>
<td>–</td>
<td>240</td>
</tr>
<tr>
<td>~100m from dump toe</td>
<td>50</td>
<td>127</td>
</tr>
<tr>
<td>Immediately below dump toe</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>~60 from toe under dump</td>
<td>40</td>
<td>92</td>
</tr>
<tr>
<td>~180 from toe under dump</td>
<td>151</td>
<td>230</td>
</tr>
<tr>
<td>210 m from toe under dump</td>
<td>200</td>
<td>230</td>
</tr>
</tbody>
</table>

Note that where the pit crest is closer than 240 m the generic (or specific if known) phreatic surface model must be merged with this model.
Phreatic surface interp. CS 28
Limit equilibrium analyses

Based on oriented borehole data and observations of core recovered from hydrological drilling the interpreted structure from the 2014 model has been modified.

The endwall crest can be located up to 180 m further south.

Existing minimum stand-off distance between dump toe and slope crest of 50m was not investigated or altered in this study.

The two easternmost endwalls require no additional buttressing or dewatering.

The most westerly (and deepest) endwall slope requires extensive toe stabilisation plus dewatering.
Cross-section 20a

Waste buttress

Buffer blast
Buttress of flat to shallow dipping strata
Conclusions

This extensive study has resulted in far better understanding of the structure and strength of critical strata beneath the waste dump toe. This improved knowledge has enabled the dump toe locality to be moved significantly closer to the pit crest thereby significantly reducing dump truck round trip distances.
Thank you

Energy Resources LLC are thanked for their assistance in preparing this presentation and for permission to share this experience.