Rock Fill Construction - Shrinkage or Bulking Factors for Rock

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Problem statement

• Over the past 8 years, MTO has received about $30M in claims related to insufficient rock—all in Northern Ontario in Precambrian shield.
• The actual quantity of rock excavation, rock fill available and/or rock fill required differed from the design quantities.
10 Task Forces for rock claims

1. Modify operating specification
2. Jurisdictional Scan
3. Geotechnical Guidelines
4. Bidding on Geotechnical Work
5. Import Rockline into HDS as DTM layer
6. Estimating Rock Backfill to Swamps
7. Bulking Factor
8. Common Design Errors
9. Construction Administration
10. Monitoring
Bulking/Shrinkage Factors

- Bulking Factor - Ratio of the volume of excavated material to the original in-situ volume before excavation
- Shrinkage Factor - Ratio of volume after compaction to volume before excavation
Rock Bulking Factor

• Reasons for study:
  – Confirmation of existing design criteria
  – Examine bulking factors for different rock types in a controlled study.
  – Unbalanced cut/fill quantities
    • Under-runs on large capital contracts
  – To support acceptance/rejection of claims
Rock Bulking Factor

• MTO used a design Bulking Factor of 1.50 i.e. An expansion of 50%
  – Used to estimate rock available for fill uses
• Range 1.25 – 1.72 (from literature)
• Varies with rock type
• No experiments to measure bulking factor in literature
Rock Bulking Factor

• 2 rock fill embankment experiments
  – Parry Sound (amphibolite gneiss)
  – Minden (granite, felsic gneiss and marble)

• Reasons for not using measurements of real fills
Rock Bulking Factor

- Detailed Ground Surveys
- 2m x 2m grid intervals
  - Prior to construction
  - Completed embankment
  - Following removal of embankment
amphibolite gneiss

CAT 245

Volvo A25C

CAT 769-C
Finished Embankment
Intermediate Survey
Measuring Mass
Calibration of Loader to Weigh Embankment – 650 loads

<table>
<thead>
<tr>
<th>Trial, (1-3 calibration)</th>
<th>Loader, mass tonnes</th>
<th>Quarry scale tonnes</th>
<th>Difference %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18.50</td>
<td>18.17</td>
<td>1.82</td>
</tr>
<tr>
<td>2</td>
<td>18.78</td>
<td>18.58</td>
<td>1.08</td>
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<tr>
<td>3</td>
<td>18.32</td>
<td>18.26</td>
<td>0.33</td>
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<tr>
<td>4 - initial</td>
<td>17.76</td>
<td>17.73</td>
<td>0.17</td>
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<tr>
<td>5 - final</td>
<td>15.92</td>
<td>15.87</td>
<td>0.32</td>
</tr>
</tbody>
</table>
Rock Bulking Factor

- Embankment Volume = 2283.083 m³
- Embankment Mass = 4646 tonnes
  - Allowance for water due to rain of 100 tonnes
- Embankment Density = 2.081 tonnes/m³
- Bedrock Density = 2.816 tonnes/m³
  Based on samples of 19 mm crushed aggregate
Rock Bulking Factor

Bulking Factor = \frac{\text{Bedrock Density}}{\text{Embankment Density}}

= \frac{2.816 \text{ t/m}^3}{2.081 \text{ t/m}^3}

= 1.353
granite, felsic gneiss and marble
• Trimmed, Compacted, Chinked
• 60m x 3m x 9m
• Blend of granite, felsic gneiss and marble
Solid Rock Densities

Average = 2.703 t/m³
Standard Deviation = 0.086
Rock Bulking Factor

Bulking Factor = \frac{\text{Bedrock Density}}{\text{Embankment Density}}

= \frac{2.703 \text{ t/m}^3}{2.005 \text{ t/m}^3}

= 1.347
Rock Bulking Factor

- Foley Quarry, Parry Sound (amphibolite gneiss) – 1.353
- Morrison Pit, Minden (granite, felsic gneiss and marble) – 1.347
- Corresponds to published University of Durham data (1997) for basalt (1.36) and granite (1.33) – but source of data is unknown and called “shrinkage factor”
Rock Bulking Factor - Conclusions

• Value of 1.50 is too high
• True value is close to 1.35 for hard, competent siliceous rock types
  – Does not consider volumes of rock created by backbreak (beyond pay line), or shatter (sub drill and blast)
• Made change to design value in highway design system
Want to read more?


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