Rock Scour Evaluation using Block Theory

*Int. Conf. on Scour & Erosion 2012*

Michael F. George, Nicholas Sitar

Dept. of Civil and Environmental Engineering – University of California - Berkeley
The Issue...

- Dam safety
- High remediation costs, loss of life
Rock Scour Mechanisms: Block Removal
Rock Scour Mechanisms

- Block failure modes

**Pure Translations**
- Lifting
- Sliding (1 plane)
- Sliding (2 planes)

**Pure Rotations**
- Rotation (edge)
- Rotation (corner)

**Slumping**

**Rotation + Translation**
- Torsional Sliding
Block Theory Basics

(Goodman & Shi, 1985)

• Removability

• Mode Analysis
  – Lifting, sliding, rotation

• Stability
Hydraulic Forces

- For variable flow conditions, assume pressure can be applied to any combination of surfaces on removable blocks
- Find most critical load
Hydraulic Forces

Characteristic Dynamic Pressure
\( (P' \ll P_m) \)

Pseudo-static Pressure
\[ P = P_s \sim P_m \]

Pseudo-static Pressure
Fluctuating pressure \( \sim 0 \)

Dynamic Impulse
\[ P = P' \cdot \sin \left(2\pi \varepsilon t + \frac{3}{2} \pi \right) + P_s \]
An Example: Dam Site in Northern CA

Unlined rock spillway
Field Data

- Field investigation to get joint orientations and spacing
  - Scan-line surveys
  - Aerial LiDAR survey
  10 removable block types
Hydraulic Forces

- Pressure head determined from USBR hydraulic jacking study (USBR, 2007) in spillway channels

Figure 29.—Mean uplift pressure, radius-edged geometry, sealed cavity, ⅛-inch gap.
3D Stability

- For each block, stability is assessed for sliding (1 and 2 planes) and lifting to find most critical failure mode.

Critical velocity = 4.4 m/s (sliding on J2 & J5)
Stability Summary

• 10 blocks total
• Range of critical flow velocities from ~ 4 to 12 m/s
• 3 blocks stable for all flow velocities
• Compare with flow velocity in spillway channel
Summary

• Block theory provides a simplistic way to incorporate 3D site specific rock structure into scour assessment
• Judgment is required to estimate water forces
• Critical areas can be targeted with detailed mapping leading to more efficient remediation designs
• Used as a planning tool to optimize orientation of new spillways with respect to rock structure
Questions?