The Future of Blasting Safety

Luke Provencher, Southeast LLC Technical Manager | VTCA December 2018
Safety Concerns of Focus

- Highwall safety discussion
- Understanding and minimizing flyrock risk
- Controlling overpressure with improved data collection
How to recognize Highwall Hazards

Highwall Instability Contributing Factors

Protective measures to ensure workplace safety
Recognizing Highwall Hazards

- Highwalls are composed of rock masses that consist of intact (solid) blocks of rock separated by structural (geological) discontinuities.

- The properties of a rock mass are not the same as the properties of the intact rock blocks.

- The properties of a rock mass include the properties of the intact rock and the properties of the discontinuities.
Recognizing Highwall Hazards

Common Types of Discontinuities

- **Bedding** – a deposit layer or surface found in sedimentary rocks.

- **Joint** – a discontinuity along which no visible movement or slippage has occurred.

- **Fault** – a discontinuity along which movement or slippage has occurred.

- **Fracture** – a generic term applied to a variety of discontinuities (all of the above).
Recognizing Highwall Hazards
Highwall Instability Contributors

- Rock Mass Properties (strength, structure, etc.)
- Highwall Geometry (angles, heights, etc.)
- Precipitation (rain, snow) Ground Water
- Face Orientation
- Freeze – Thaw Cycles
- Equipment Vibrations
- Blasting
Highwall Instability Controls

Adequate Catch Benches

Inadequate Catch Benches
Workplace Safety Measures

- Workplace safety inspections before conducting any work
  - Does highwall need to be scaled?
  - Are the catch benches full?
  - Is the wall fresh or weathered?

- Determine minimum safe working distance
  - Does work need to be conducted too close to highwall?
  - Are additional control measures required?

How close is too close??
Adequate Highwall Clearance

Factors to consider
- Highwall height (H)
- Berm height (B)
- Berm Distance (D)

Open Discussion
- When do you need a berm?
- What is a safe berm height?
- What is a safe berm distance?
Understanding Flyrock Risks of Blast Designs

- What are the varying levels of flyrock risk based on shot design?

- What are the primary parameters to influence flyrock risk?

- How can we quantify the associated risk?
Understanding Collar Ejection Flyrock Risk

Scale Depth of Burial (SDoB): Driver for Launch Velocity

Uncontrolled Energy
Violent flyrock, airblast, noise and dust.
Very fine fragmentation.
Good craters.

Controlled Energy
Good fragmentation.
Maximum volume of broken rock in collar zone.
Acceptable vibration/airblast.
Good heave and muck pile mound.

Very Controlled Energy
Larger fragmentation.
Reduced volume of broken rock in collar zone.
Acceptable vibration/airblast.
Reduced heave and muck pile mound.
No flyrock.

Minimal Surface Effects
Small surface disturbance.
Insignificant surface effects.

Crater Ejection

Mounding

Minimal Disturbance

EXPANSION OF THE PANAMA CANAL

by

R. Frank Chiappetta
BLASTING ANALYSIS INTERNATIONAL INC.
Allentown, Pennsylvania, USA

Tom Treleaven
THE ENNISON-RICKFORD COMPANY
Simsbury, Connecticut, USA

SEVENTH HIGH TECH SEMINAR
Blasting Technology, Instrumentation
and Explosives Applications

Orlando, Florida, USA
July 28 - August 1, 1997
Studying Collar Ejection Flyrock Risk

High SDoB: Minimal Disturbance
Studying Collar Ejection Flyrock Risk

Moderate SDoB: Mounding
Studying Collar Ejection Flyrock Risk
Studying Flyrock Risk

Aggressive SDoB: Mild Crater Ejection
Studying Collar Ejection Flyrock Risk
Studying Collar Ejection Flyrock Risk

Low SDoB: Complete Crater Ejection
Studying Collar Ejection Flyrock Risk
Calculating Collar Ejection Flyrock Risk

SDoB calculated based off:

- Explosives Diameter
- Stemming Length
- Explosive Density
- Charge Length

As SDoB decreases, particle exit velocity increases.
Defining Hole Load Strategy

Set SDoB Parameters for ALL holes in pattern

- Stemming
- Hole Diameter
- Column Length
- Product Density
Defining Collar Ejection Risk Based on Hole Loads

Flyrock Calculator
- Individual Hole

- Stemming
- Column Length
- Hole Diameter
- Product Density
Shot Design Based on Collar Ejection Flyrock Risk
Shot Design Based on Collar Ejection Flyrock Risk

- 4.5” Holes
- 15’ Stemming
- 8’ Powder Column
- ANFO (0.85 g/cc)

118ft Max. Flyrock Projection Risk
Shot Design Based on Collar Ejection Flyrock Risk

- 4.5” Holes
- 10’ Stemming
- 13’ Powder Column
- Gassed Emulsion (1.18 g/cc)

Max. Flyrock Projection Risk: 309ft
# Evaluating Face Ejection Flyrock Risk

## Flyrock Projection and Risk Analysis

### Rock Properties
- **Rock Density**: 2.65 g/cc

### Pattern Geometry
- **Hole Diameter**: 6.500 in
- **Bench Height**: 40.0 ft
- **Sub-Drill**: 3.0 ft
- **Min. Front Row Burden**: 7.0 ft

### Charge Configuration
- **Min. Stemming Length**: 8.0 ft
- **Air**: 0.0 ft
- **Base Charge Expl. Type**: ANFO
- **Base Charge Weight**: 428 lb (max)
- **Base Charge Length**: 35.0 ft
- **Base Charge Density**: 0.85 g/cc
- **Base Charge RBS**: 100%

### Column Charge Expl. Type
- **ANFO**
- **Column Charge Weight**: 0.0 lb
- **Column Charge Length**: 0.00 ft
- **Column Charge Density**: 0.85 g/cc
- **Column Charge RBS**: 100%

### Statistics for Collar Fragment with Maximum Projection
- **Fragment Size**: 3.1 in
- **Fragment Wt.**: 1.7 lb
- **Launch Vel.**: 281 mph
- **Max. Height**: 555 ft
- **Impact Vel.**: 72 mph

### Random Fragment Statistics
- **Fragment Size**: 4.0 in
- **Max. Collar Projection Distance**: 840 ft
- **Max. Face Projection Distance**: 1457 ft

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Flyrock Safety Statistics

- **Max. Collar Proj. Distance**: 863 ft
- **Fragment Size, Collar**: 3.1 in
- **Max. Front Row Proj. Distance**: 1509 ft
- **Fragment Size, Front Row**: 5.5 in
- **Equipment Clearance**: 900 ft
- **Dist. to Personnel**: 1500 ft
- **Equipment Factor of Safety**: 60%
- **Personnel Factor of Safety**: 99%

Scenario: 6.5 inch, 8 ft stem, ANFO

Maximum Fragment Trajectories

- **Distance (ft.)**: 0, 200, 400, 600, 800, 1000, 1200, 1400, 1600
- **Height (ft.)**: 0, 50, 100, 150, 200, 250, 300, 350, 400, 450
- **Trajectories**: Stem (0.0 ft), Collar, Equipment, Personnel
Shot Design Based on Collar Ejection Flyrock Risk
Flyrock Calculator – Factor of Safety (FoS)

What is FoS?

\[
\text{FoS} = \frac{\text{Distance to Point of Concern (ft)}}{\text{Max Potential Flyrock Projection (ft)}}
\]

\[
\frac{500 \text{ ft}}{350 \text{ ft}} = 1.43 \text{ FoS}
\]
Identifying Minimum Face Burdens

2D Laser Profiling Vs. 3D Modelling

Challenges of blast design – We must have an efficient and accurate means to determine the necessary placement of our boreholes relative to the open face.

Two primary systems used today:
- 2D profiling with manual design
- 3D modelling with software design
Pros:
- Fast and reliable for small scale blast design
- Quick reference for face heights and floor levels

Cons:
- Only provides 2D representation of face
- Manual process that can be susceptible to human error
Pros:
- Gives true representation of working face
- Accurate volume calculations
- Can be synced with “smart” equipment
  - Drills, loaders, diggers, haul trucks, etc.

Cons:
- Expensive equipment and software
- Data collection and model rendering is time consuming
- Requires software training to design blasts
Burdens from 2D Profile

2D Burdens: 13’ – 19’ Up face
Burdens from 3D Profile (Minimum Burdens)

3D Burdens: 10’ – 14’ Up face
Comparing 2D vs. 3D Profiles

3D Burdens: 10’ – 14’ Up face

2D Burdens: 13’ – 19’ Up face
Understanding Overpressure Risk

Primary Contributing Factors

- Stemming
- Face burdens
- Distance/Orientation to POI
- Weather
- Timing
- Hole Loads

What factors are easiest to control?

How can we measure their influence?
Assign Parameters
- Stemming
- Face Burdens
- Timing
- Hole Loads
Designing for Overpressure Risk

Face hole properties
- Define min. burdens
- Based off 3D
Designing for Overpressure Risk

Apply timing
- Traditional
- Radial
- Per-Distance
Designing for Overpressure Risk

House 1

House 2

House 3

House 4

House 5
Designing for Overpressure Risk
Designing for Overpressure Risk

<table>
<thead>
<tr>
<th>Location</th>
<th>Peak Overpressure</th>
<th>Arrival Time</th>
<th>Distance to Blast</th>
</tr>
</thead>
<tbody>
<tr>
<td>House 1</td>
<td>1,288 ft.</td>
<td>1.138 ms</td>
<td>in front of blast</td>
</tr>
<tr>
<td></td>
<td>117.1 dB</td>
<td></td>
<td>Behind blast</td>
</tr>
<tr>
<td></td>
<td>111.5 dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>House 2</td>
<td>1,065.4 ft.</td>
<td>941 ms</td>
<td>in front of blast</td>
</tr>
<tr>
<td></td>
<td>123.7 dB</td>
<td></td>
<td>Behind blast</td>
</tr>
<tr>
<td></td>
<td>113.7 dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>House 3</td>
<td>1,301.6 ft.</td>
<td>1.150 ms</td>
<td>in front of blast</td>
</tr>
<tr>
<td></td>
<td>119.5 dB</td>
<td></td>
<td>Behind blast</td>
</tr>
<tr>
<td></td>
<td>107.6 dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>House 4</td>
<td>1,185.7 ft.</td>
<td>1.048 ms</td>
<td>in front of blast</td>
</tr>
<tr>
<td></td>
<td>125.6 dB</td>
<td></td>
<td>Behind blast</td>
</tr>
<tr>
<td></td>
<td>113.9 dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>House 5</td>
<td>1,136.8 ft.</td>
<td>1.004 ms</td>
<td>in front of blast</td>
</tr>
<tr>
<td></td>
<td>120.7 dB</td>
<td></td>
<td>Behind blast</td>
</tr>
<tr>
<td></td>
<td>108.9 dB</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Compare Timing Scenarios

• Timing Scenario 1

• Timing Scenario 2
Compare Timing Scenarios

• Timing Scenario 1

Overpressure At Location
Displays the peak overpressure at the selected locations

House 1: 1,288 ft, arr. time 1,138 ms
117.1 dB, in front of blast
111.5 dB, behind blast

House 2: 1,065.4 ft, arr. time 941 ms
123.7 dB, in front of blast
113.7 dB, behind blast

House 3: 1,301.6 ft, arr. time 1,150 ms
119.5 dB, in front of blast
107.6 dB, behind blast

House 4: 1,185.7 ft, arr. time 1,048 ms
125.6 dB, in front of blast
113.9 dB, behind blast

House 5: 1,136.8 ft, arr. time 1,004 ms
120.7 dB, in front of blast
108.9 dB, behind blast

• Timing Scenario 2

Overpressure At Location
Displays the peak overpressure at the selected locations

House 1: 1,288 ft, arr. time 1,138 ms
118.8 dB, in front of blast
112.9 dB, behind blast

House 2: 1,065.4 ft, arr. time 941 ms
121.8 dB, in front of blast
112.7 dB, behind blast

House 3: 1,301.6 ft, arr. time 1,150 ms
118.5 dB, in front of blast
110.5 dB, behind blast

House 4: 1,185.7 ft, arr. time 1,048 ms
120.1 dB, in front of blast
110.3 dB, behind blast

House 5: 1,136.8 ft, arr. time 1,004 ms
120.9 dB, in front of blast
112.3 dB, behind blast
Improved Decision Making

Ability to make educated decisions based on high quality design data

- Improved Flyrock awareness through 3D models and FoS planning
- Improved overpressure predictions through minimum burdens

What are some additional applications?

- Vibration control and prediction
- Highwall damage modelling
- Fragmentation analysis/prediction