Influence of Geology on Ground Vibrations from Rock Blasting

City of Henderson Community Meeting
Monday, March 27, 2017

Henderson Multigenerational Center
250 S. Green Valley Parkway
Rock Blasting Studies – City of Henderson

2005
Vibration attenuation modeling
Structure response study
Close-in monitoring of a buried water tank

2005 - present
Review of blasting permit applications

2016-2017
Influence of geology on vibrations
Dr. Cathy Aimone-Martin
Blasting and Monitoring Consultant to the City of Henderson
President, Aimone-Martin Associates, LLC

25 years Chair Mining, Civil, Explosive Engineering, NM Tech

Specializations in
  mining, quarrying, construction blasting oversight
  instrumentation and measurements
  close-in vibration and air blast pressure control
  underwater blasting and aquatic species protection
  education and training

Projects
  World Trade Center, 2nd Ave.
  Panama Canal
  Dam/Spillway reconstruction
  SFOBB pier demolitions
  Skagway Bridge replacement
Vibration and Air Overpressure Monitoring Basics involves the use of blasting-type seismographs, geophones, and microphones.
TERMS:

Peak particle velocity (PPV) – maximum ground vibration in terms of velocity (in/s)

“airblast” – air pressure converted to decibels (dB)

frequency – oscillations (cycles) of ground/air motion/second (Hz)
This presentation will focus on blast-induced ground vibrations and factors that affect the amplitude or intensity of vibrations at any one monitoring location.

These factors include:

- Blast-site energy (blast design and confinement)
- Attenuation (or decrease) of ground energy between blast site and monitoring location
- Methods used to deploy or couple geophones to the ground
- Geology surrounding the geophone
Recommended standards for the manufacture and use of blasting seismographs are set by the International Society of Explosives Engineers (ISEE)

- Seismograph Committee – Field Practice Guidelines
- Standard Committee – Performance Specifications
These professional guidelines ensure that

• users are experienced and trained,

• seismographs are in calibration, and

• uniform field deployment for geophones and microphones is followed
Plotting and analyzing ground vibration measurements

1. Attenuation modeling used to design blasts and predict PPV

\[ PPV = K \times SD^{-b} \]

- Increase in PPV with distance, D and charge weight, W
- Scaled distance, SD (D/W^{1/2})
$PPV = K \cdot SD^{-b}$

- $K$: seismic energy in the ground at the blast site
- $b$: rate of decrease in PPV with distance as influenced by geology
2. Compliance with vibration regulations and safe standards

- City of Henderson regulation
March 2005 - Studies conducted for the City of Henderson

- Vibration attenuation modeling – influence of geology and terrain
- Structure Response to Blasting & Environmental Impacts
City of Henderson Attenuation Model for all directions
slope, b \((-1.5)\) indicative of uniform geology
K-factor of 122 typical of geologies throughout the US

![Graph showing attenuation model with equation PPV = 121.6 SD\(^{-1.50}\) and R\(^2\) = 0.93]
The US Bureau of Mines found similar trend for coal mine blasting.

\[ PPV = 119 \, \text{Ds}^{-1.52} \]

**Diagram:**
- **Title:** US Bureau of Mines
- **Ref:** RI 8507 (1980)

**Axes:**
- Y-axis: Particle Velocity, in/sec
- X-axis: Square Root Scaled Distance, ft/\text{lb}^{1/2}

**Legend:**
- Key points:
  - Horizontal H-1
  - Horizontal H-2
  - Vertical
March-April 2005

Structure Response Study
(High Mesa and Big Horn Ridge)
Exterior seismograph

mid-wall

crack and null gages

upper corner

lower corner

temperature/humidly sensor
weather-induced change in crack width:
daily 6844 micro-inch
over 5 weeks 8212 micro-inch
largest blast-induced
33 mph wind-induced

244 micro-inch
277 micro-inch

Crack displacement during wind gust 3/23/05 at 2:15 am

Crack displacement during blast 3/23/05 at 2:47 pm
Conclusions drawn from this study:

Compared with blasting near the PPV limit (0.45 in/s)
- wall strains from weather changes were 72 times greater
- crack displacements were 34 times greater than the blast near the

33 mph wind gusts produced crack displacements 10% greater than those produced from blasting near the regulatory limit.
2016-2017 Study of the Sunridge Communities:
Are houses built on “fill” subjected to ground vibrations that are
different from houses founded on a “cut”, natural (undisturbed) ground, and rock?

(prepared by VCE based on Google Earth imagery)
Aimone-Martin was provided

- vibration records from VCE that included blast information
- maps of blast and seismograph locations
- map of cut/fill areas

Measurements were plotted

- with the site attenuation model developed in 2005 and
- within the City of Henderson limit of 0.5 in/s
Preliminary assessments were made based on the following:

- geology of seismograph locations designated by fill, cut, natural (virgin) soil, and rock near the surface from VCE
- redundant monitoring provided by Aztec for side-by-side comparisons
9 monitoring locations: 3 Fill, 1 Cut, 3 Rock, 2 Natural
Data available from VCE 10/19/16 to 3/14/17 and from Aztec 2/8/17 to 3/14/17

<table>
<thead>
<tr>
<th></th>
<th>VCE deployed</th>
<th>VCE triggered (%)</th>
<th>Aztec deployed</th>
<th>Aztec triggered (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut</td>
<td>110</td>
<td>86 (78%)</td>
<td>32</td>
<td>22 (67%)</td>
</tr>
<tr>
<td>Natural</td>
<td>117</td>
<td>87 (74%)</td>
<td>30</td>
<td>25 (69%)</td>
</tr>
<tr>
<td>Rock</td>
<td>27</td>
<td>23 (85%)</td>
<td>12</td>
<td>9 (75%)</td>
</tr>
<tr>
<td>Fill</td>
<td>106</td>
<td>52 (49%)</td>
<td>24</td>
<td>12 (50%)</td>
</tr>
</tbody>
</table>

Total:
VCE: 360
Aztec: 248
Fill: 98

Aztec data fall exactly in line with 2005 attenuation model. VCE data show slightly higher upper bound scatter.
VCE data scatter is attributed to coupling method of geophone that often included a sandbag weight overlying the geophone.

- this is an optional ISEE-approved method for coupling to the ground.
- method often results in slight higher measurements which is considered to be conservative.
Seismograph measurements

- **Peak Particle Velocity (in/s)**
  - Major damage: 8.0 in/s
  - Minor damage: 3.0 in/s
  - US Bureau of Mines threshold cracking limit: 0.75 in/s
  - City of Henderson Limit: 2.0 in/s

- **Cut**
- **Natural**
- **Rock**
- **Fill**

Graph showing seismograph measurements with peak particle velocity on the y-axis and peak frequency on the x-axis.
Preliminary findings

• Blasting is not the cause of cracking structures

• The presence of fill tends to attenuate vibrations more than cut, rock, and natural soils

There will be a summary White Paper of findings on the website
QUESTIONS