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Extreme ground motion studies

James N. Brune
University of Nevada, Reno, brune@seismo.unr.edu

John G. Anderson
University of Nevada, Reno, jga@seismo.unr.edu

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Extreme Ground Motion Studies
Task ORD-FY06-022

PI’s: James N. Brune and John G. Anderson
Nevada Seismological Laboratory,
University of Nevada, Reno
NSHE Cooperative Agreement Interim Progress Briefings
January 18, 2007, Reno, Nevada
Subtasks

1. Constraints on Yucca Mountain extreme ground motion based on precariously balanced rocks, unstable precipitous cliffs, and un-fractured sandstone along the San Andreas fault.

2. Prepare summary report on large recorded ground motions.
Record Holders: Extreme Values of Recorded Acceleration and Velocity

John G. Anderson, Justin A. Flint, Nicholas C. Hockensmith, James N. Brune

Note: All results are preliminary and Non-Q.
Initial Results

• Peak Acceleration:
  – Top 100: 597 cm/s$^2$ - 2369 cm/s$^2$.
  – 25 records with pga > g.

• Peak Velocity
  – Top 100: 52 cm/s - 318 cm/s.
  – 32 records with pgv > 100 cm/s.
1. 2004 Parkfield: FZ16
2. Nahanni: site 1
3. Northridge: Tarzana
4. Cape Mendocino: Petrolia
5. Niigata: Tohkamachi
6. Northridge: Pacoima Dam
7. 1979 Imp. Valley: Sta. 6
8. Niigata: Ojiya
9. San Fernando: Pacoima Dam
10. Gazli: Karakyr

Peak Acceleration ($\text{cm/s}^2$)
1. Chi-Chi: TCU068
2. Northridge: Rinaldi
3. Yountville: Napa
4. Kobe: Takatori
5. Landers: Lucerne
6. Chi-Chi: TCU065
7. Tabas: Tabas
8. Cape Mendocino: Petrolia
9. Chi-Chi: TCU052
10. Niigata: Ojiya
Hypothesis on Spikes

- On at least some strong-motion records, large, high-frequency spikes are caused by brittle failure of near-surface rock beneath the station.
- This failure is triggered by the strong strains during high-amplitude, long period velocity pulses.
Chi-Chi
TCU068
Implications

• Brune proposed that high-velocity pulses would cause the rock under Yucca Mountain to fracture.
• These records may be examples of such events.
• Models for the extreme accelerations might need to take into account the high-frequency energy created by nonlinear processes in near-site rocks.
Is there historical evidence for stronger motions?

• A few observations of rocks that have been thrown horizontally by earthquakes.
• Review by Saburoh Midorikawa
  – 44 cases reported (not complete)
  – 7 cases with throw > 1 - 2 m
  – 9 cases with throw 2-4 m
  – No cases with throw >4 m
• Will any of the accelerograms collected in this project throw a boulder?
DISPLACED BOULDERS NEAR KANCHI, KHASI HILLS.
thrown 8 1/2 ft. from its original position. About quarter of a mile from this a group of small Khasia monoliths, some 6 ft. high, had been destroyed, not by breaking off, nor by upsetting, but by shot upwards out of the ground as indicated in fig. 14. One of these had travelled 6 1/4 ft. through the air from the place where it was shot.
Model Rock Thrown Into the Air

- Vertical (cm)
- Height (cm)
- Horizontal E (cm)
- Throw E (cm)
Records in Database

YM: $10^{-8}$ per year

YM: $10^{-7}$ per year

YM: $10^{-6}$ per year

Peak Velocity, cm/s

Peak Acceleration, g
Combinations of peak acceleration and peak velocity that will throw rocks >150 cm and <400 cm, based on multiplying accelerograms in collection by a constant.
Conclusions

• These are preliminary, non Q results.
• Some high frequency, high acceleration spikes on observed accelerograms might be caused by nonlinearity in the “near surface” geology - e.g. upper 2-3 km.
• By the intensity measure of ability to throw rocks, none of these records come close to the largest historical observations. Minimum criteria for throwing rocks still need to be studied.
UNEXCEEDED GROUND MOTIONS-YUCCA MOUNTAIN AND SAN ANDREAS FAULT

JAMES BRUNE
## Summary of Point A Peak Values

<table>
<thead>
<tr>
<th>APE</th>
<th>Mean PGA (g)</th>
<th>Mean PGV (cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horizontal</td>
<td>Vertical</td>
</tr>
<tr>
<td>$10^{-7}$</td>
<td>5.838</td>
<td>8.652 (tension)</td>
</tr>
<tr>
<td>$10^{-6}$</td>
<td>2.860</td>
<td>4.124</td>
</tr>
<tr>
<td>$10^{-4}$</td>
<td>0.534</td>
<td>0.715</td>
</tr>
<tr>
<td>$5 \times 10^{-4}$</td>
<td>0.245</td>
<td>0.254</td>
</tr>
</tbody>
</table>

PGA = Peak Ground Acceleration  
PGV = Peak Ground Velocity  

$E \sim 3 \text{ m/s} / 3 \text{ km/s} = 10^{-3}$
Seismic Drift Stability - Lower Lithophysal Unit
(tensile failure)

Example Results

5x10^-4, unsupported

1x10^-6, unsupported

- Results
  - 5x10^-4 - sidewall spalling only
  - 1x10^-6 and 1x10^-7 - similar damage - rock failure over drip shield - primary impact is dead weight load on drip shield

- Damage levels for low prob. events not consistent with observations of no damage in lithophysae in Exploratory Study Facility

Preliminary Draft Materials
Shattered rock, hanging wall, thrust fault
Note human for scale
Typical Cliff face At Yucca Mountain >100,000 years?
Tentative conclusion from Yucca Cliffs: No evidence for extreme ground motions in $> 100$ ka
San Andreas sandstone locations

\[ \sim 20,000 \, M \sim 8 \text{ events} \]

\[ [a, v] \, M = 8 \text{(s.a.)} > \]

\[ [c) \, a, v] \, M = 7 \text{ (y.m).} \]}
Although the precise erosion rate of the sandstones is not known, probably no such avalanches have been created in the last 250 ka. The suggested upper limits on ground motion are consistent with the current instrumental strong motion data set (covering about 50 yrs), and, in addition, suggest that the large NTS-type ground motions have not occurred over a much longer history of the San Andreas Fault.
Refraction Microtremor for Shallow Shear Velocity
ReMi measures Rayleigh dispersion with linear refraction arrays (paper by Louie, April 2001 BSSA).

A. Section of 30 s Noise Record from 200 m Array at Newhall Fire Station
B. Velocity-Spectral Analysis of Noise Array
C. Noise Array Rayleigh Dispersion
D. Rosine vs. Noise Array at Newhall F.S.

Initial funding from SCEC, UNR, VUW, Optim LLC
Lines 101 and 102 Nested

First 2 Cajon ReMi Lines 9/18/06

Distance East of 117.46720 (#1256), m.

Line 101
285 m

Line 102
152 m
Energy/Slowness/Frequency Plot - Line 101
Shear Velocity vs. Depth Model- Line 101

Line 101

Vs30 = 506 m/s