Rotational Motions Extracted from Delaney Park Downhole Array in Anchorage, Alaska

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Delaney Park Geotechnical (DPK) Array

- DPK array is located at northwest downtown Anchorage.
- The array was installed in 2003 in a collaboration between UAA, USGS, NSF and UC Santa Barbara.
- It is now maintained jointly by the USGS and UC Santa Barbara.
Ground motions are measured at the surface and at six levels below the surface using borehole accelerometers.

Accelerometers record motions in the glacial outwash sediments near the surface, the clays of the bootlegger cove formation, and at its deepest into the glacial till.
Schematic Plan of the Delaney Park Downhole Array

- Data Recorder
- D0
- D1
- D2
- D3
- D4
- D5
- D6

Dimensions:
- 1.7 m
- 1.8 m
- 2 m
- 2.1 m
- 2.9 m
- 4.5 m
- 7.6 m

North (N) direction indicated by red arrow.
Earthquake Recordings

DPK Array recorded the M7 November 30, 2018 Anchorage Alaska Earthquake (epi dist=14.3 km, Depth=40.9 km) and a series of aftershocks including the M5.7, M4.8 and other smaller ones.
Delaney Array Recordings of November 30, 2018
M7.0 Anchorage Earthquake

<table>
<thead>
<tr>
<th></th>
<th>D0</th>
<th>D1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acceleration cm/s/s</td>
<td>Velocity cm/s</td>
</tr>
<tr>
<td>HNN</td>
<td>245.6</td>
<td>15.95</td>
</tr>
<tr>
<td>HNE</td>
<td>247.3</td>
<td>24.64</td>
</tr>
<tr>
<td>HNZ</td>
<td>294.1</td>
<td>7.64</td>
</tr>
</tbody>
</table>
Displacements in Downhole
Downhole Displacement
Displacements in Downhole
Deformation (simple shear) in the downhole along the $x$-axis

where $x_n(t)$ and $x_{n-1}(t)$ are amplitudes of horizontal ground motions at the same time $t$ at different elevations in the downhole, and $L$ is the distance between those elevations measurements (base).

Simple shear strain with the rate $\gamma$ is the combination of pure shear strain with the rate $\gamma/2$ and rotation with the rate of $\alpha=\gamma/2$. 
Deformations at Depths

2.3 m
7.6 m
14.5 m
24.4 m
53.2 m
Deformation
Maximum Deformation, Acceleration, Velocity and Displacement Decay

Maximum Deformation

\[ y = 0.0234x^{-0.994} \]

Maximum Acceleration (cm/s/s), Velocity (cm/s) and Displacement (cm) vs Depth

\[ y = 0.0246x^{-1.068} \]
M5.7 Downhole Deformations
Comparison of Deformation and PGA, PGV and PGD Decay with Depth

Deformation decays faster with depth than PGA, PGV and PGD.
Maximum Deformations at Depths

<table>
<thead>
<tr>
<th>Delaney Array</th>
<th>D0-D1 (2.3 m)</th>
<th>D2-D1 (7.5 m)</th>
<th>D3-D2 (14.5 m)</th>
<th>D4-D3 (24.4 m)</th>
<th>D5-D4 (38 m)</th>
<th>D6-D5 (53.2 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M7.0</td>
<td>8.70E-03</td>
<td>3.96E-03</td>
<td>2.61E-03</td>
<td>8.67E-04</td>
<td>6.14E-04</td>
<td>3.66E-04</td>
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<tr>
<td>M5.7</td>
<td>2.23E-04</td>
<td>1.16E-04</td>
<td>8.26E-05</td>
<td>6.74E-05</td>
<td>8.76E-05</td>
<td>7.50E-05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eureka Array</th>
<th>9.5 m</th>
<th>26 m</th>
<th>44.5 m</th>
<th>96 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/10/2010 M6.5, R=54 km</td>
<td>1.20E-03</td>
<td>7.60E-04</td>
<td>3.90E-04</td>
<td>2.70E-04</td>
</tr>
</tbody>
</table>

![Maximum Deformation Diagram]
Concluding Remarks

• Data recorded by downhole arrays with sensors installed at different depths and geologic layers provide important information to study site amplification and other site effects.

• Downhole arrays’ recordings obtained during a number of recent earthquakes provide an opportunity to estimate deformation, shear and rotational component of ground motion, and apparently were not previously used for this purpose.

• High dynamic range, synchronized and properly oriented array instrumentation is necessary for reliable calculation of deformations.

• Very large deformations are calculated based on strong-motions at the DPK array during the 2018 M7 Anchorage Alaska earthquake. Such large deformations suggest non-linearity at soft soil layers.
Thanks ...