DOES CASING MATERIAL INFLUENCE DOWNHOLE ACCELEROMETER RECORDINGS?

A CONTROLLED STUDY OF EARTHQUAKE AND EXPERIMENTAL DATA RECORDED AT THE NEES@UCSB WILDLIFE LIQUEFACTION ARRAY

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ABSTRACT

In 2004, NEES@UCSB outfitted the Wildlife Liquefaction Array (WLA) with new instrumentation and initiated an experiment to test whether casing material influences downhole recordings of strong ground motion. Two 5.5m boreholes were drilled one meter apart. One of the boreholes was cased with traditional rigid PVC and the other with flexible Corex® drain pipe. Three-component strong-motion accelerometers were installed in both boreholes. Recently we have obtained a unique set of data at WLA that has allowed us to conduct a controlled study.

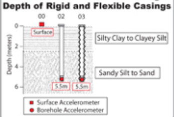
On 15 June 2010, a Mw 5.7 event occurred near Ocotillo, CA, 57 km SW from WLA. A set of 60 aftershocks with M>3.0 were recorded at WLA with good signal-to-noise ratio. These data are ideal for our study, as the events are approximately colocated relative to the site and they have similar focal mechanisms.

We computed frequency spectra for the three components of motion for these events and we computed average spectral ratios between the data in the two boreholes. The spectral ratios are not flat (= 1): certain frequencies within the range of engineering interest (f < 20 Hz) recorded in the flexible borehole show amplification and damping relative to the recordings from the rigid borehole. An amplification factor of 1.4 is the maximum in this frequency range.

In May 2010, NEES@UTexas visited WLA with the vibroseis truck T-Rex. We have performed spectral analysis of borehole recordings from 30 T-Rex pulses with frequencies ranging from 3 to 16 Hz. We present these spectral ratios for comparison with the ones computed from earthquake data.

THE EXPERIMENT

Cross Section of WLA Showing Depth of Rigid and Flexible Casings



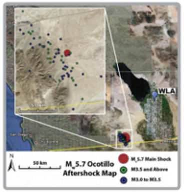
When WLA was re-instrumented in 2005 an experiment was initiated with the goal of determining if casing material affects accelerometer recordings. Two 5.5m boreholes were drilled one meter apart and outfitted with Kinemetrics Shallow Borehole EpiSensors (SBEPI) three-component accelerometers. One borehole was cased with the traditional 4in rigid PVC pipe and the other was cased with 4in flexible Corex® drain pipe.[1]

For more information on the experiment, the site, the instrumentation or the installation procedures please refer to "Instrumentation of the Wildlife Liquefaction Array" by Youd et al.

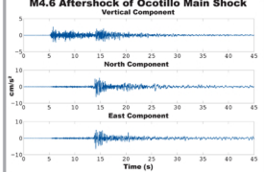
Flexible Corex® Casing
Image Retrieved From: http://www.homedepot.com

THE EARTHQUAKE DATA

Over 2,000 events have been recorded by the sensors at WLA. For this analysis we are using the dataset of 60 aftershocks with M>3.0 from the 2010 Ocotillo Swarm. This dataset is unique because of the large number of events that are relatively colocated in relation to WLA and have similar focal mechanisms.



This image is a map showing main shock and all 60 of its aftershocks with good signal-to-noise ratio.

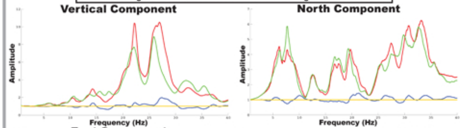


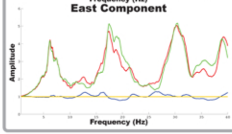
The figure above is the data recorded by the surface accelerometer at WLA of the largest aftershock of the M_w 5.7 main shock.

SPECTRAL ANALYSIS OF THE EARTHQUAKE DATA

Spectral Ratios for the Three Components of Motion

—Surface to Rigid —Surface to Flexible —Flexible to Rigid —Reference Line

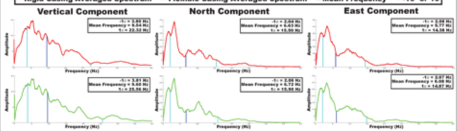




These plots are the average spectral ratios for the three components of motion. For each of the 60 events of magnitude greater than 3.0 (M > 3.0), the surface-to-downhole spectral ratio is computed for each component. These ratios are then averaged over all events. The red line is the average spectral ratio computed for the borehole with the rigid casing. The green line is the average spectral ratio computed for the borehole with the flexible casing. The blue line is the average spectral ratio computed between the borehole with the flexible casing and the borehole with the rigid casing. This figure demonstrates that in the frequency range of engineering interest, the casing material does have an impact on the recorded signal.

Mean and Standard Deviation of Average Spectra of Rigid and Flexible Casings

—Rigid Casing Averaged Spectrum —Flexible Casing Averaged Spectrum —Mean Frequency —-1σ or 1σ



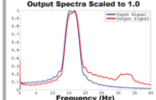
THE EXPERIMENTAL DATA

NEES@UTexas' T-Rex visited WLA in May of 2010 and generated controlled srong-motion.

When NEES@UTexas visited WLA with T-Rex in May of 2010 they performed more than 100 different 'shake tests' of frequencies ranging from 3 to 16 Hz. We have began analysis of these tests. The tests vary in several ways including distance from the site, amplitude, direction and frequency.

It is clear from the image to the right that the frequency input into T-Rex is very similar to the spectrum that T-Rex actually generates.

T-Rex Signal Input and Measured Output Spectra Scaled to 1.0

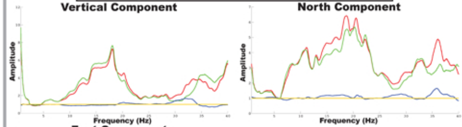


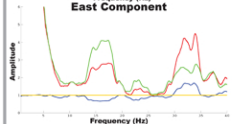
This figure is an example of the spectra that T-Rex produced at WLA when shaking with an input signal of 16 Hz

SPECTRAL ANALYSIS OF THE EXPERIMENTAL DATA

16 Hz T-Rex Spectral Ratios for the Three Components of Motion

—Surface to Rigid —Surface to Flexible —Flexible to Rigid —Reference Line





During the experiment, T-Rex was located 10m south of the site. The input signal was a 16Hz sine wave over one second duration on the vertical axis. In the figures, the green line is the average spectral ratio computed between the signals recorded at the surface and in the borehole with the flexible casing. The red line is the average spectral ratio computed between the signals recorded at the surface and in the borehole with the rigid casing. The blue line is the average spectral ratio computed between the signals recorded in the borehole with the flexible casing and the signals recorded in the borehole with the rigid casing

This analysis has been conducted for 30 of the shake tests ranging from 3 to 16 Hz. All of the images show that there are differences between the recordings from the borehole with rigid casing and recordings from the borehole with flexible casing.

FUTURE STUDIES

Our study of the data from the Ocotillo swarm clearly shows that the signals recorded in the two boreholes have different amplitudes at frequencies below 40Hz.

The next step in our study is to investigate the physical properties of the borehole casings that have an impact on earthquake signals. Possible effects include damping by energy absorption or amplification of certain frequencies where the casing serves as a waveguide. We plan to compute theoretical transfer functions for the Wildlife Site and compare them to the earthquake and T-Rex experimental data. Comparison with theoretical amplifications in the frequency domain can help identify the influence of the different casing materials on the signal.

Kinematics Shallow Borehole EpiSensor Being Lowered into a Borehole

REFERENCES

Thomas L. Holzer and T. Leslie Youd. Liquefaction, ground oscillation, and soil deformation at the Wildlife Array, California. Bulletin of the Seismological Society of America, 97(3):961-976, 2007.

[1]T. L. Youd, J. H. Steidl, and R. A. Steller. Instrumentation of the Wildlife Liquefaction Array. In Proceedings of the Fourth International Conference on Earthquake Geotechnical Engineering, 2007.