Laboratory and Field Testing of Two Rotational Seismometers

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Overview

- Two each of commercial rotational velocity sensors, Eentec Model R-1 and PMD Model RSB-20
- Lab Testing
- Field Testing
- Earthquake Monitoring
- Ambient Monitoring in Buildings

Acknowledgements

- Willie Lee
- Central Weather Bureau of Taiwan
- George Liu of IES
- Kinemetrics – Outhay Viengkhou and Rudy Diaz
- NEES@UCSB – Jamie Steidl
- NEES@UCLA

Eentec R-1 specs

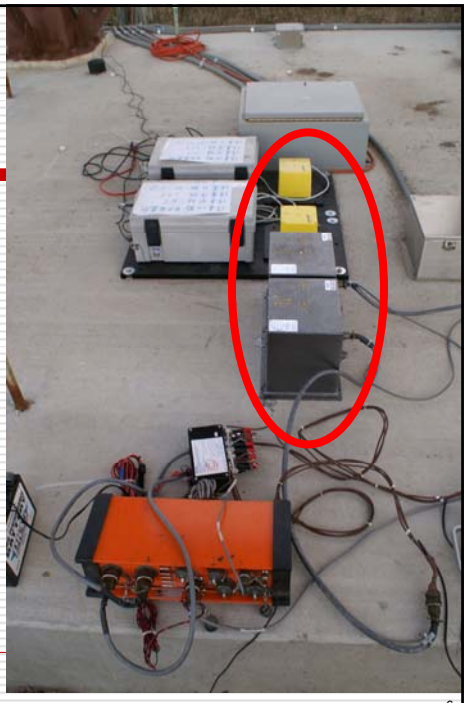
- Triaxial rotational velocity sensor
- Electrochemical technology (magnetohydrodynamic)
- 0.05 – 20/50 Hz bandwidth
- 50V per radian/sec
- ~0.1 radian/sec clip
- ~micro radian/sec noise (108dB specified)
- 20mA from 9-14VDC power
- 12 x 12 x 9cm
- 1kg
- Watertight (NEMA-4)

PMD RSB-20 (prototype) specs

- Triaxial rotational velocity sensor
- Electrochemical technology (magnetohydrodynamic)
- 0.01 – 50 Hz bandwidth
- 50V per radian/sec
- ~0.1 radian/sec clip
- Sub-micro radian/sec noise (144dB specified)
- 28mA from 9-14VDC power
- 16 x 16 x 16cm
- 2kg
- Watertight

Sensor Testing, Aug.-Nov. 2006

- Electronic, Noise, Shake Table Testing at UCLA
- Field Testing at NEES@UCSB's Garner Valley Array
- Temporary deployments in 2 UCLA buildings
- Connected to K2 Accelerographs and Q330 Dataloggers



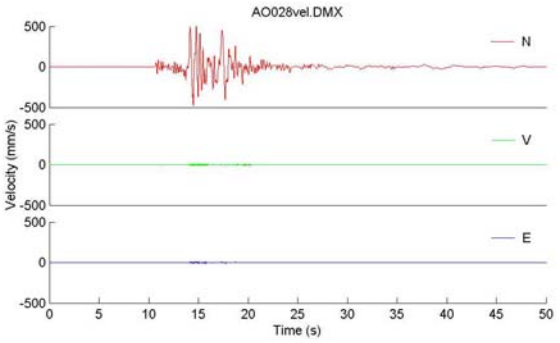
Basic Testing

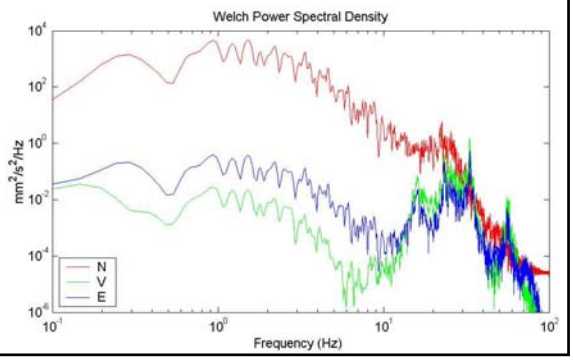
Test	R-1 #122	RSB-20 #10602
Startup Current @12VDC	~100mA	~400mA
Steady-State Current @12VDC	25mA	35mA
Voltage step sensitivity	no	yes
Clip Recovery	Tens of seconds	minutes
Warm-up Time	Several Minutes	~10 Minutes

Shake Table Testing

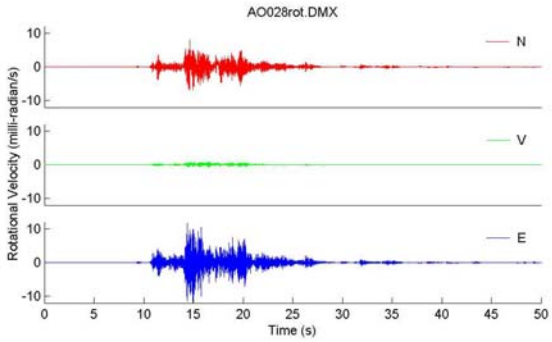
- UCLA 1-D linear shake table
- Purpose: Look at cross-axis & large motion response
- Also intended to develop rotational fixture, but these sensors are too sensitive (0.1 rad/sec is SMALL)
- Findings: Cannot separate table rattling effects from potential cross-axis

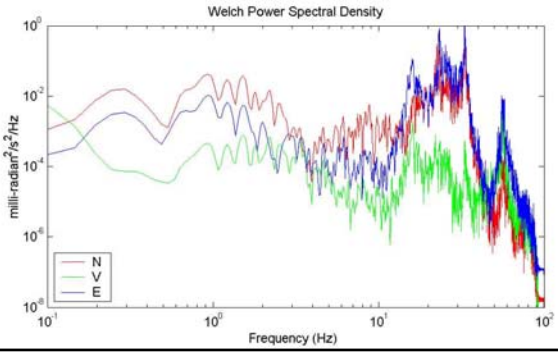
Shake Table Accelerations for Simulated Earthquake





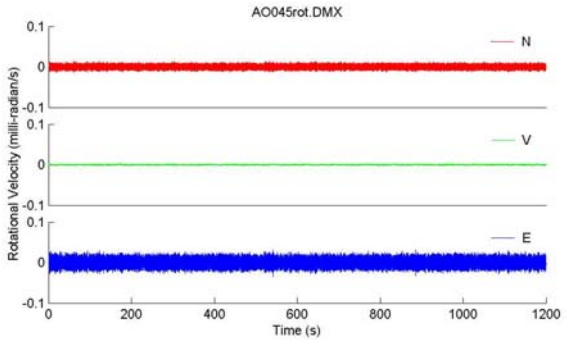
Measured Rotation Signals for Simulated Earthquake (R-1)

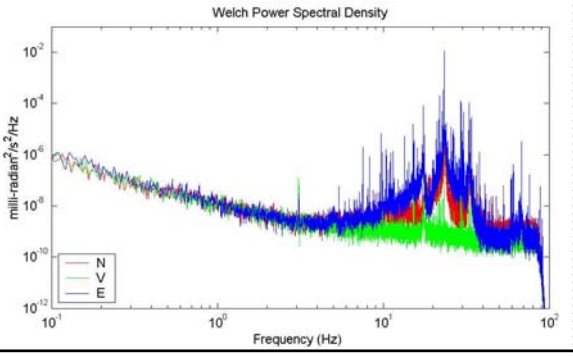




Sensor Noise (R-1)

- **Measured in building basement in urban area, so is an upper bound**
- **R-1 Noise <0.01 milli-radian/sec rms**
- **RSB-20 instability prevented long-duration noise measurement**





Field Deployment

- On SFSI test structure at the GVDA array
- Two K2 19-bit accelerographs w/internal accelerometers & external rotation sensors
- Ambient & triggered monitoring for ~6 weeks
- Forced vibration testing with small shaker and hammer

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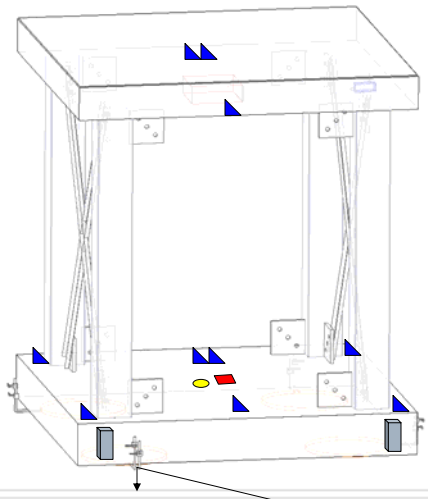
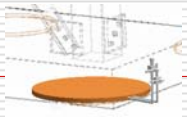
•3D Geotechnical Arrays at 2 permanent field sites in Southern California
•Soil-Foundation-Structure-Interaction (SFSI) Test Structure

- Real earthquake data
- Test bed for geotechnical and geophysical methods
- Location for active experiments in a well-characterized field setting

SFSI Test Structure Instrumentation

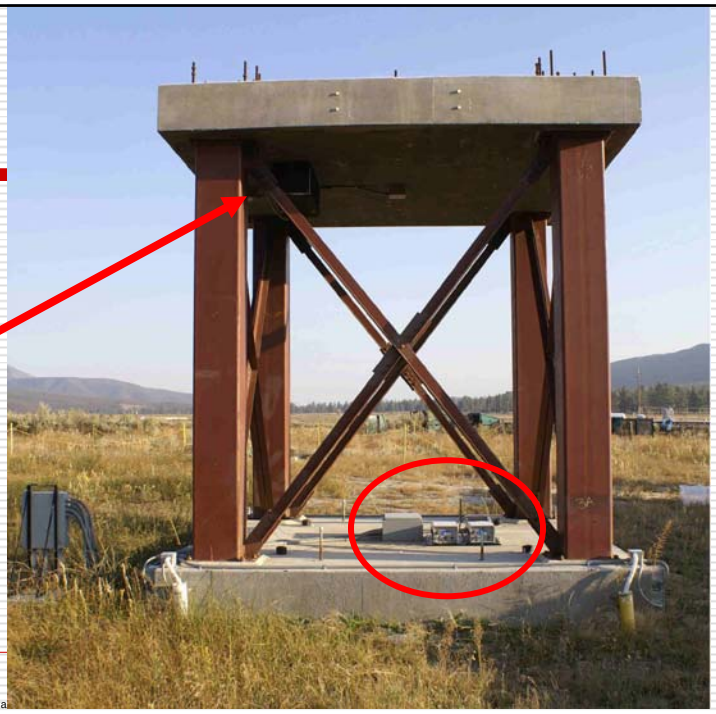


Pressure Cell and Sensor

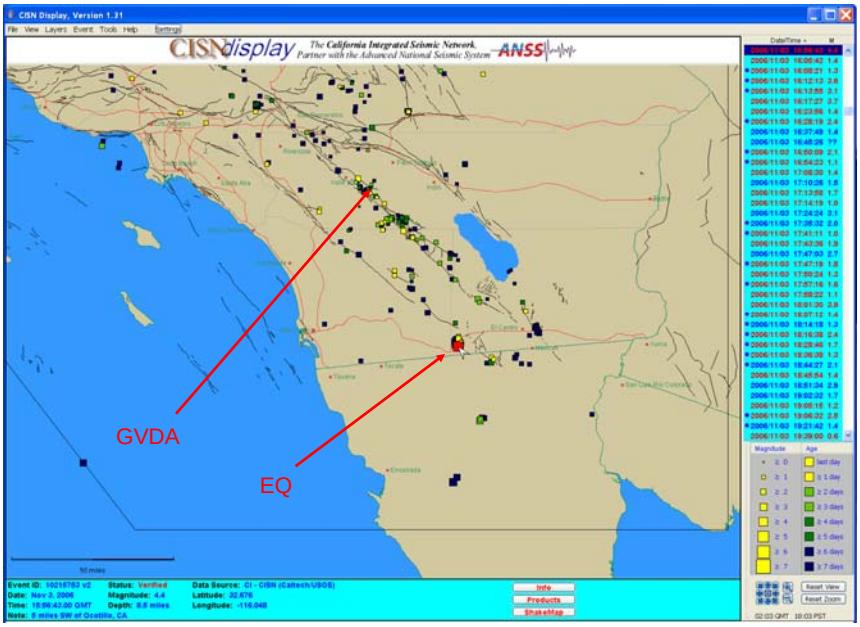


Uni-axial Accelerometer
Tri-axial Accelerometer
Rotation Sensor
Displacement Transducer

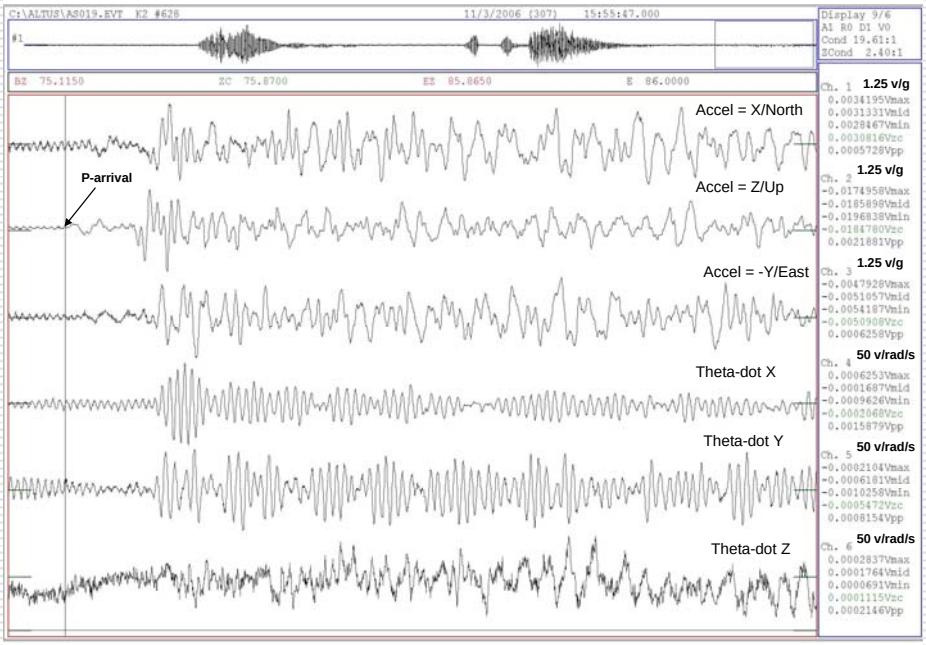
100-lb Shaker, Remote Internet Control



M4.4 Earthquake, 11/3/2006 15:56:43 GMT, ~120km from GVDA

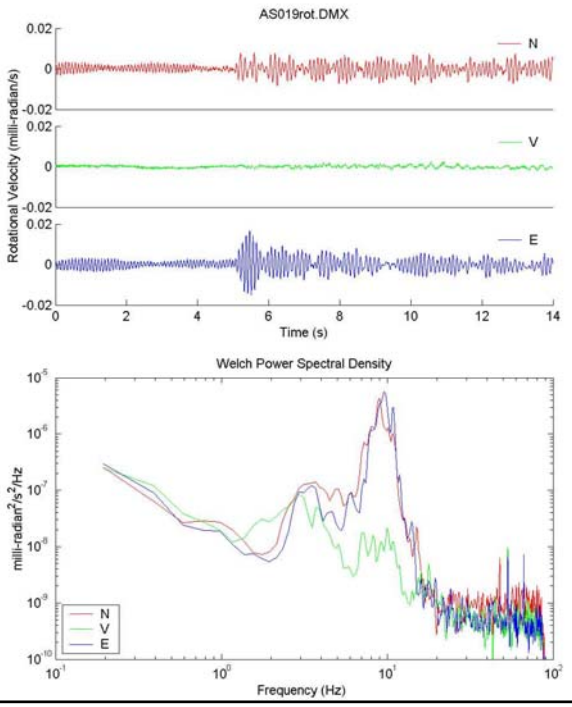


File AS019.evt, System 2: M4.4 event subset (P-coda only)



Measured Rotational Velocities for P-wave coda

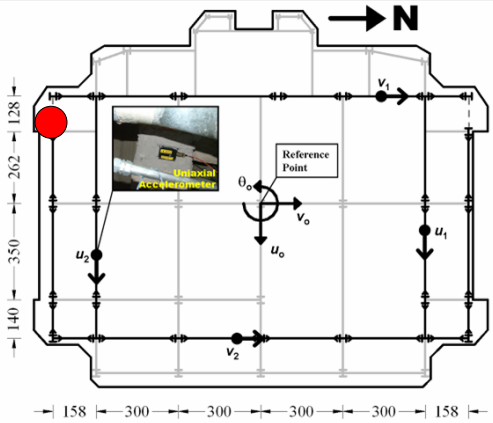
10-Hz peaks are the SFSI structure rocking modes



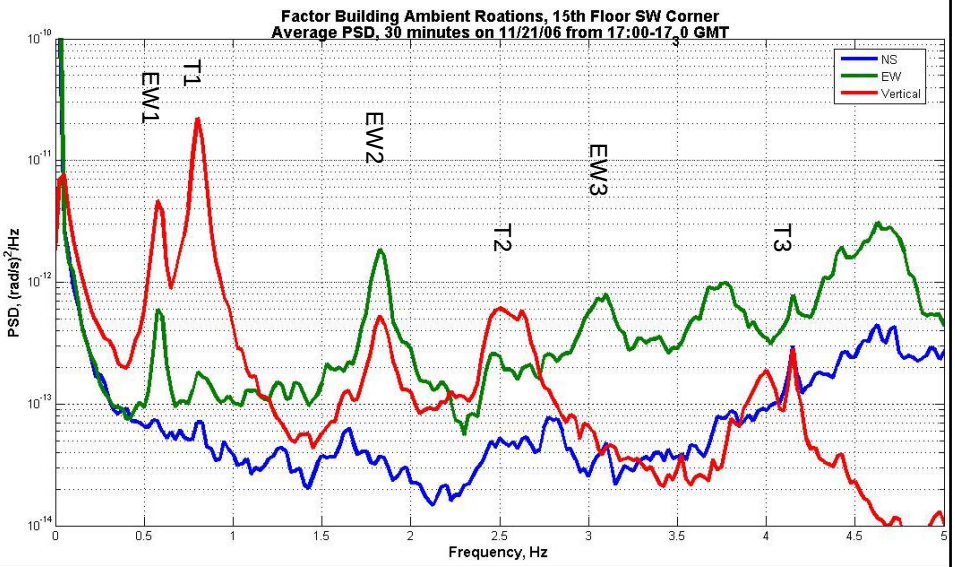
Structural Response Measurements

- Boelter Hall at UCLA
- Factor Building at UCLA
- Temporary deployments at each to measure ambient vibrations
- R-1 with 24-bit datalogger (Q330) works well

Factor Building: ANSS-Instrumented w/ 72 accelerometers



Rotation sensor location on 15th floor



Summary

- **Two samples each of the Eentec R-1 and PMD RSB-20 (prototypes) were tested in lab and field for ~3 months**
- **These are highly-sensitive rotational broadband seismometers, and must be treated more like broadbands than strong motion sensors**
- **R-1 performance was good**
- **The RSB-20 prototypes had some instability issues that hindered testing – the manufacturer is working on solutions**
- **Cross-axis and more rigorous performance testing will require special rotational test fixtures (rotational shake tables) to isolate individual rotational components of motion**
- **An earthquake and ambient & forced structural vibrations were measured – analysis is in progress**