Ambient Vibration H/V Spectral Ratio (HVSR) Method Field Testing Guidelines

QuakeCoRE Technology Platform 2

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Sensor installation and data acquisition

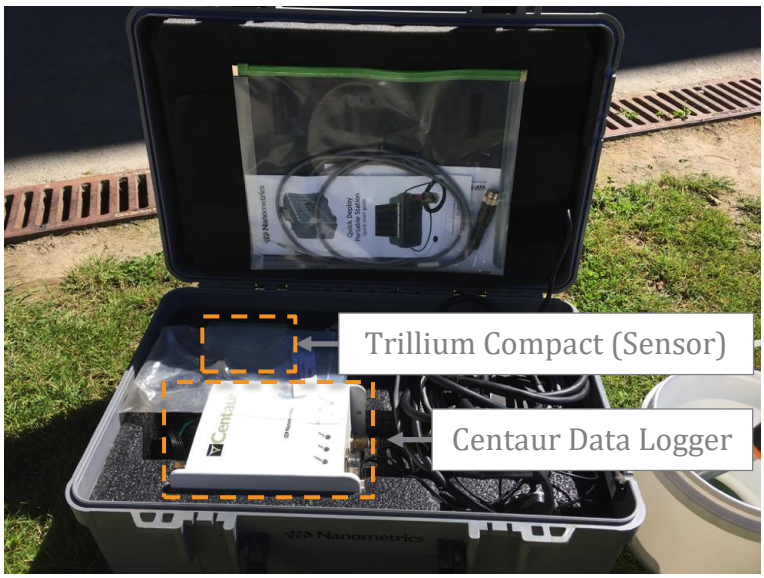
List of required items

- Nanometrics portable broadband seismometer (all equipment in case)
- Trowel and pick (if buried)
- Compass
- Bucket and weight (sandbag or paver)
- Cradles and nails (optional)
- Data sheet(s) and pencil/pen

Steps-by-step instructions for installation

First steps for installation

1) Open the equipment box and confirm that the Trillium Compact broadband seismometer (the sensor) is not connected at this stage.



2) Power on the Centaur data logger, if it is not turned on already, by connecting the battery with the power controller as shown in the photo below.

3) Deploy the GPS antenna as shown in the photo below. It is recommended to do this first because it takes a short period of time for the GPS receiver to lock on the satellites. The GPS is used to synchronize the timing of the Centaur data logger.

Trillium compact (Sensor) placement

Option 1 (Preferred) – Cradle on paved surface

This sensor placement method is advantageous due to (1) the minimal time required for setup and (2) the apparent best resolution when characterising deep impedance contrasts. However, **care must be taken to limit the rocking of the sensor in the cradle.**

The **sensor cradle** is required for this placement method.

1) Place the cradle on the hard (e.g., paved or sealed) ground surface. Ensure that the cradle is stable and does not easily rock with a gentle push.

2) Place the sensor in the cradle. Ensure that the sensor and the cradle will not easily rock or shift during testing. Otherwise, consider alternative sensor placement.

3) **Orient and level the sensor. Precisely orient the sensor to magnetic north using a compass,** with the N arrow on top of the sensor indicating the orientation of the North component of the sensor. Do not hold the compass in close vicinity to the sensor, as it will affect the compass reading. **Ensure the sensor is level** by carefully adjusting the sensor position until the bubble level on top of the sensor is centred inside the marked circle.

Option 2 – Buried in shallow hole

This method is advantageous when (1) sensor rocking is a concern and (2) the soil is soft enough to dig a small hole and easily compact around the sensor.

A trowel and/or pick are required for this placement method.

1) Dig a small hole of about 10~12cm in diameter, 7~8cm in depth. If the soil is covered by turf, use the trowel to "cut" 10 to 12-cm diameter hole and set the turf aside prior to digging the deeper hole. Place the sensor in the hole and check that the hole will allow the seismometer to be levelled once filled it. **Ensure the soil under the sensor is well packed down. Precisely align the sensor to magnetic north using a compass**, with the N arrow on the top of the sensor indicating the N direction on the sensor. Do not hold the compass in close vicinity to the sensor, as it will affect the compass reading. **Ensure the sensor is level** by carefully adjusting the sensor position until the bubble level on top of the sensor is centred inside the marked circle.

2) Fill the gap around the sides of the sensor with soil and tightly pack. **It is critically important that the soil is tightly packed from the bottom up.** It is recommended to use a trowel to pack down the soil in layers around the sensor. **Again, check that the sensor is aligned to north and that the seismometer is still level.**

3) Ensure that there is no long grass, or similar, touching the top of the sensor (e.g., anything that can blow in the wind and disturb the sensor). Remove any grass if this is the case.

Option 3 – Cradle on stiff soil

This placement method is advantageous in terms installation time and should be used when a hard paved/sealed surface is not suitable and the surface soil is stiff. However, **the installer must be careful to prevent the rocking of the sensor.** If the surface soil is noticeably soft this approach is not recommended.

A sensor cradle and nail (as shown below) are required for this placement method.

1) On the unpaved ground, lay down the cradle, and drive down the nail using a hard object and body weight as shown in the photo below. **Make sure that the cradle does not rock by checking with a gentle push.**

2) Place the sensor on the cradle. **Align the sensor towards magnetic north.** The orientation of the N-S component of the sensor is indicated by the N arrow. **It is important to take the compass readings slightly away from the sensor**, because the sensor will interfere with the compass needle. **Level the sensor**; this is verified by ensuring the bubble level on the top of the sensor is centred in the marked circle.

Final steps for installation

1) Remove the red cap, protecting the connector pins, and connect the sensor (i.e., Trillium Compact) to the data logger (i.e., Centaur). **Always connect the cable to the sensor first**. This is done to ensure that the sensor is not accidentally disturbed when powered on.

2) **Tidy up the cable** by (a) loosely wrapping the cable around the cradle, as shown in the photo above or (b) loosely coiling the cable next to the buried sensor. In both cases, it is important to **ensure that the cable does not touch sensor.** Again, this is done to prevent accidental disturbance of the sensor and limit transient noise during recording. Remove any long grass or other debris touching the sensor cable.

3) Verify again that the sensor is oriented towards magnetic north and level.

4) Carefully cover the sensor with a bucket. The bucket should have (1) a notch cut on its side to allow the cable to run between the sensor and data logger, and (2) small hole on its top to allow the visual verification that the sensor is properly oriented and levelled. Place a weight (e.g., a small sand back or a paver) on top of the bucket. **Make sure that the bucket will not rock with a gentle push, and once the bucket has been placed make sure that the seismometer has not moved before placing the weight.**

5) Connect the sensor cable to the data logger.

6) Make sure all LEDs on the top of the Centaur data logger are green and close the equipment box. As shown below, **the cables MUST be carefully routed through the designated grooves to prevent damage.** Optionally, the GPS antenna may now be placed on top of the box.

7) At this point the sensor and data logger are installed and prepared for data acquisition. Wait five minutes, allowing the sensor to "settle" before acquisition of "good" ambient vibration data.

8) During the settlement period, begin and write the test/site field notes on the data sheet, including: (1) the test/site location, (2) a 3 or 4 character site/location name (e.g., LOC1 and LOC2, or BGPK and ARBD) to use for identification in data analysis and archival, (3) the start time of the data acquisition period (i.e., the end of the settlement period), (4) sensor installation details, and (5) any site other pertinent site conditions or details (e.g., weather, sources of transient and continuous vibrational

noise, any difficulties with the instrumentation). A photograph of the instrumentation setup is also very helpful.

9) After the settlement period, avoid any activity near the instrumentation to limit transient noise. Ensure that the wind does not disturb (e.g., rock) the bucket or the data cable.

10) Allow the station to record ambient vibrations for at least 30 minutes. Depending on the depth of the soil profile and the profile characteristics, a longer minimum duration may be necessary. If the station is installed in a secure location, it can left for a longer duration.

Steps-by-step instruction for removal

1) When testing is complete, write down the end time of data acquisition onto the field data sheet and disconnect the sensor from the data logger. Do not move and limit the disturbance of the sensor prior to disconnecting it from the Centaur data logger. The sensor data cable should be disconnected from Centaur data logger and the sensor. Carefully remove the weight and bucket.

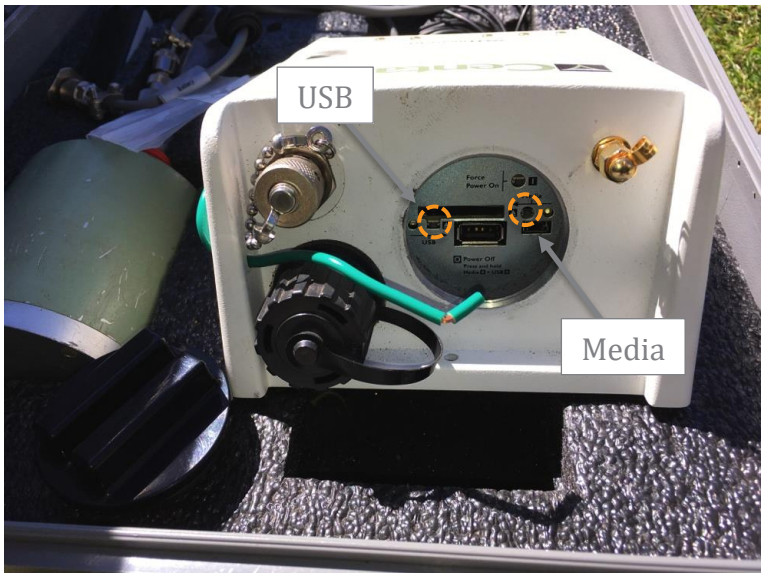
2) Extract the sensor from the ground or remove off the cradle. Brush/clean off any soil from the sensor and/or the cradle. Cover/protect the data connection pins on the sensor by replacing the small red cap. Place all items back to where they belong in the instrument box. **Before closing the instrument box for transport to the next site, tidy up the equipment and cables, and remove any soil, grass, leaves, etc. from the box.**

3) If a hole was dug, do a reasonable job of refilling the hole and replace any turf. Use judgement depending on the quality of the site in the first instance.

4) If there are more sites to test during the day, the Centaur data logger can be left on during transport to the next site. Remember that at each site (after each test), the seismometer must always be disconnected as above prior to transport.

   If testing is completed, wait until the hour during which testing was undertaken has completed prior to turning off the Centaur (process outlined below). This ensures that all data is saved onto the SD cards for data download.

5) **To turn off the Centaur data logger, open the media bay as shown in the following photo and simultaneously press down 'USB' and 'Media' eject buttons for about three seconds**, until the indicator LED lights of the Centaur logger start blinking orange. **BE CAREFUL to not touch, disturb, or remove the SD card while pressing the buttons.** Wait until all the indicator lights turn off. This ensures all of the data is properly stored on the SD card.



6) Disconnect the battery from the power supply cable.

7) When the Centaur data logger is turned off, the SD card can be removed. Carefully close the instrument box, ensuring no cable is pinched.

8) At the end of the field testing trip, it is important to ensure that the instrumentation box, the Centaur data logger, the Trillium sensor, and the cables are clean and tidy. Clean out any soil, grass, leaves, etc. from the instrumentation box. Wipe down/clean the Centaur, Trillium, and cables with a rag or shop towel. Remove/brush/blow out any soil/dust from the sensor data cable connections. Check that cable/wire connections are secure (especially, the power wires between the battery, the junction box, and the centaur unit).

A bit of maintenance and cleaning at the end of each trip will ensure that the equipment is ready and properly functioning for future field trips.