Some Notes on Using the Partial Demolition of the Hoan Bridge to Estimate the Thickness of the Continental Crust under Milwaukee

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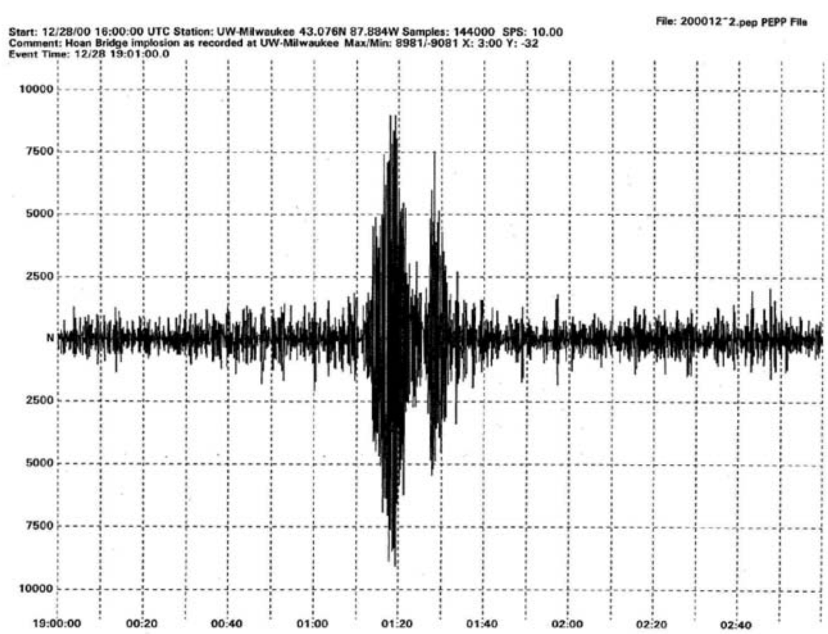
The Hoan Bridge on Interstate Highway 794 in Milwaukee, Wisconsin, sustained a partial failure of one of its main steel support beams on December 13, 2000.

To prepare the bridge for repair, explosive charges were set around the perimeter of the damaged section. Just after 1 PM local time on December 28, 2000, the charges were detonated and the damaged bridge section fell to the ground below, generating an elastic wave that was sufficiently strong to bounce off the top of the mantle under Milwaukee and be recorded by the seismograph at the University of Wisconsin-Milwaukee 6 km to the north. YouTube videos of the demolition are available at
http://www.youtube.com/watch?v=pS_HdhOBik8
http://www.youtube.com/watch?v=vRz797o_l-k (with the explosion occurring 3 minutes 27 seconds into the video) and http://www.youtube.com/watch?v=x6AxV9WbvIk The damaged part of the bridge was subsequently rebuilt, and is now back in service.

A seismogram containing all 3 components of the motion recorded at the University of Wisconsin-Milwaukee (UWM) is provided to students, along with a worksheet. If this is done as an in-class exercise, a few slides are displayed and video clips shown to set the stage, and in particular a slide is displayed that contains an initial print of the transverse-component seismogram. The waveform on this image is not as clear as on the handout, but the beginning of the two signals (direct wave and reflected wave) is probably clearer.



The direct wave arrives at UWM at around 19:01:11.6 UTC, and the reflected wave arrives around 13 seconds later.

In trying to interpret both the record shown above and the seismograms on the student worksheet, we are confronted with uncertainty in the time picks for both of these waves. This will frustrate students, but do not neglect to utilize this teachable moment. It is very useful to have a classroom discussion of the uncertainty your students encounter in identifying the first arrival of these two waves – after all, recognizing, accepting, and dealing with uncertainty is a fundamental activity of any scientist.

As shown in the YouTube videos, part of the uncertainty in this analysis involves the somewhat complicated sources of the seismic signals. First, there was a nearly-synchronous series of explosions ~120 feet above the ground to free the damaged section from the rest of the bridge. The airburst probably did not cause a significant seismic signal at UWM, but some of the energy from the explosions was transmitted down the concrete piers of the bridge and into the ground. The impulse from the explosion was transmitted into the ground a couple of seconds before the damaged bridge section hit the ground, generating the first seismic wave from the event. The second dollup of energy is related to the impact of the bridge section, which appears to have settled onto the ground in less than a second after initial impact. And then the remaining bridge structure vibrated for several seconds after the demolition, transmitting additional vibrations through its concrete piers to the ground. The complexity of the echo reflected off the Moho reflects this complex source.

The analysis on the worksheet involves a reconstruction of the exact origin time of the impact, using a near-surface seismic velocity that is not well constrained. We use an estimate of 5 km/sec, but the actual value is a function of the material properties along the ray path. Between the impact site and UWM, there are Holocene lake sediments, early Holocene swamp/bog deposits, late Neogene glacial deposits, and Paleozoic dolostone formations atop Precambrian igneous and metamorphic rock. The actual velocity might range from a bit below 5 km/sec to just over 6 km/sec if the raypath was channeled through intact dolostone; however, most of the near-surface carbonates are jointed, which would result in slower velocity. For lack of any other control, we use 5 km/sec.

The 6.0 km distance between the UWM seismograph and the impact site is well constrained using GPS.

Some References

Braile, L.W., 1989, Crustal structure of the continental interior, *in* Pakiser, L.C., and Mooney, W.D., Geophysical framework of the continental United States: Boulder, Colorado, Geological Society of America Memoir 172, p. 285-315.

Christensen, N.I., and Mooney, W.D., Seismic velocity structure and composition of the continental crust -- A global review: *Journal of Geophysical Research*, v. 100, no. B7, p. 9761-9788.

Lichtenstein Consulting Engineers archives on the Hoan Bridge: http://web.archive.org/web/20070311050511/www.lce.us/Hoan/