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Comparison of SPAC methodologies and results for a microtremor survey over deep soft sediments, Christchurch, New Zealand

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The Hagley Park site, Christchurch, New Zealand was one of 14 sites used in a study of passive and active surface wave methods, for determination of a shear-wave velocity (Vs) profile of a thickness of several hundred meters of Holocene and Pleistocene interbedded sands, silts, clays and gravels. The field data used circular arrays of nine stations (plus centre station) with radii 60m, 200m and 400m. Teague et al (2015) used MSPAC and f-k, supplemented by MASW, to compare Vs models for monotonically increasing Vs with depth, with Vs models containing multiple low-velocity layers. In this blind study the data is interpreted using direct-fitting of observed and model SPAC curves (the multiple-mode SPAC method, MMSPAC). Five results emerge.

1)Direct fitting of SPAC curves allows use of frequencies up to 14 Hz (the 5th maximum of the coherency curve) compared with a maximum of 3 Hz from MSPAC. These frequencies correspond with minimum depths of investigation of 35m and 2.5m respectively.

2)The better shallow depth resolution of direct fitting allows clear resolution of a low velocity layer (LVL) in the vicinity of 2 to 4.5 m depth, from SPAC methods alone.

3)Part of the wave energy propagates as a higher mode at frequencies 1.5-2Hz. This feature was also detected using MSPAC, but direct fitting including use of the Rayleigh effective mode (a superposition of modes where the energy partition is computed for ideal point sources on a layered earth) shows that the observed fraction of energy is less than that for the theoretical effective mode, and it is time dependent (different for the 200m and 400m arrays). Neither processing method is able to quantitatively use observed data in the frequency band, but the direct fitting method yields a clearer demonstration of the multiple modes and variability of the mode fractions.

4)The MSPAC interpretation used an a priori gradational Vs variation over 25 layers whereas the direct fitting assumed a minimum number of 12 layers with larger velocity contrasts. Even with assistance of H/V spectra the two model types appear interchangeable, illustrating the difficulty of resolving a unique layering structure with surface-wave methods. Apart from resolving a single near-surface LVL the direct fitting method offers no advantage in discriminating multiple LVLs, affirming Teague et al (2015) that integration of borehole log and well-log data is essential for interpretation of surface-wave data in areas with complex geology.

5)When the 9-station circle is decimated to a triangular array the quality of the direct fitting is reduced but not significantly. For the 200m array the useful frequency range extends to the 7th maximum of the SPAC curve (7Hz) both before and after the decimation. The useful low frequency limit of 0.5 Hz is also unchanged. When a single 2-station subset is selected from the 200m array the quality of the SPAC curve is significantly poorer but remains useful over a reduced frequency range 0.5-5.5Hz.

The results here downgrade the need for complementary active surface-wave studies at such sites. The quality of data from a minimal triangular array, and to a lesser extent from a 2-station array, supports Hayashi et al (2016) that routine passive seismic surveys with minimal arrays may be sufficient for characterizing the Vs profile, without the logistical costs of complex circular arrays and complementary active seismic surveys. Future blind trials such as those in the INTERPACIFIC and COSMOS projects should include comparisons of results on minimal array geometries as well as benchmarking methodologies with complex arrays.