Use of SPAC, HVSR & Strong Ground Motion Analysis for Site Hazard Study in Launceston

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Summary: The geology of Launceston (Tasmania) is characterised by soft Tertiary and Quaternary sediments filling the Tamar rift valley. We use SPAC and HVSR microtremor survey methods, and strong ground motion analysis to study the resonance pattern at 2 sites: *GUN* located over assumed 1D geology, and *KPK* inside the Tamar valley. Observed HVSR at *GUN* fits the modelled ellipticity (R_0) from SPAC analysis with a 1D earth model. Difference between HVSR and modelled strong ground motion analysis is explained by the input of damping and modulus reduction factors in the strong ground motion analysis. Observed HVSR at *KPK* do not agree with modelled R_0. We suggest the presence of 2D effects from the Tamar valley. We explain the difference between HVSR and strong ground motion analysis at *KPK* by a mix of potential 2D effects from the valley, and the use of damping and modulus reduction curves in the strong ground motion analysis.

Introduction

The Tamar valley (Figure 1, blue outline) is filled with soft sediments from the Tertiary and Quaternary periods, overlying hard dolerite bedrock. The bedrock provides a good base for foundations, but the soft sediments can induce amplification of ground motion. We postulate likelihood of existence of a 2D seismic resonance pattern. We study the seismic resonance pattern and site amplification in Launceston, combining the use of spatially averaged coherency method (SPAC), horizontal to vertical spectrum ratio method (HVSR), and strong ground motion analysis. We present data recorded at 2 sites: *GUN* located over assumed 1D layered geology; and *KPK* inside the Tamar valley (Figure 1).

Methodology

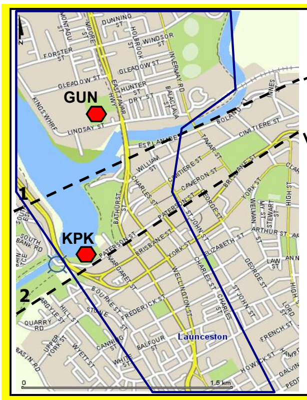
1. Evaluate shear wave velocity (SWV) profiles using SPAC, with centred hexagonal arrays (Figure 1, inset). We use 2 arrays at *GUN* ($r_{1(a)}$=15m, $r_{1(b)}$=30m); and 1 array at *KPK* (r_1=28m). By forward iterative modelling (Hermann, 2002), we directly fit the observed averaged coherency to a Bessel function:

$$C(\omega) = J_0\left(\frac{2\pi f r}{V(f)}\right)$$

where *C(ω)* is the spatially averaged coherency, J_0 the Bessel function, *f* the frequency, *r* the inter-station separation, and *V(f)* the shear wave velocity dispersion curve associated to a layered earth model.

2. Evaluate the pattern of resonance at *GUN* and *KPK* using 3 different techniques:

- With SWV profiles from SPAC, evaluate the ellipticity of Rayleigh wave particles motion (R_0). At period of resonance, the motion tends to degenerate to an horizontal motion.
- Observed HVSR is empirically found to estimate R_0 of a layered earth model, thus estimating the period of resonance. Previous studies show the period of resonance over 2D valley is shifted to shorter period.
- Evaluate amplification factor by modelling regolith site response, using spectral acceleration from strong ground motion on hard rock. Use the package *SUA* (Robinson *et al.* 2003).



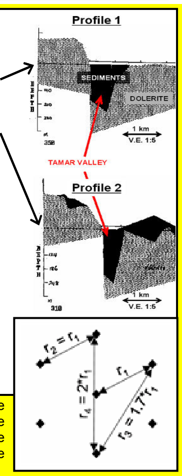
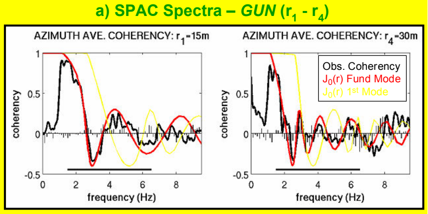


Figure 1. Map of Launceston. Red hexagons are locations of SPAC array. Dashed black lines are gravity profiles from Leaman (1994). Blue outline is the limits of Tamar valley. Inset (right) is the centred hexagonal array used for SPAC.

Results – Site *GUN*

a) SPAC Spectra – *GUN* (r_1 - r_4)



b) SWV Profile–*GUN*

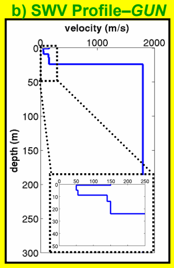
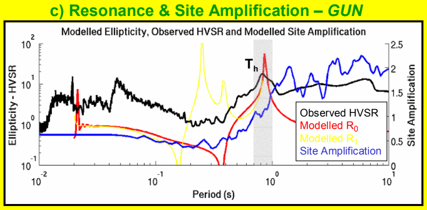


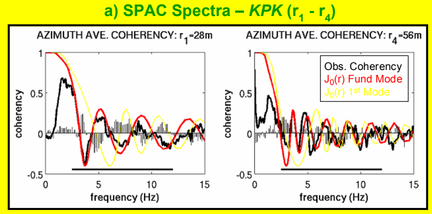
Figure 2.
a) SPAC spectra at site *GUN*, r_1=15m and r_4=30m. Observed coherency (black curve) fit to Bessel function (red and yellow curves) for *f* = 1.5 to 6.5Hz.
b) SWV profile at *GUN* from SPAC analysis. Inset shows details of the first 50m: 1m of filling on top, 8m of low velocity (50m/s) alluvial sediments (clay and silt), 15m of more coherent silty clay to clayey sand, hard dolerite bedrock at a depth of 24m.
c) Period of resonance (T_h) from HVSR, R_0 and site amplification from strong ground motion analysis (Table 1). Grey rectangle outlines T_h from observed HVSR.

c) Resonance & Site Amplification – *GUN*



Results – Site *KPK*

a) SPAC Spectra – *KPK* (r_1 - r_4)



b) SWV Profile–*KPK*

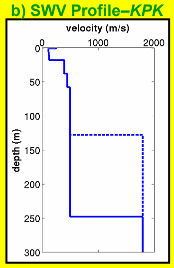
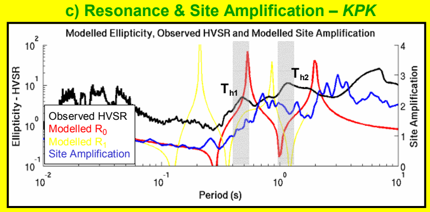


Figure 3.
a) SPAC spectra at site *KPK*, r_1=28m, and r_4=56m. Observed coherency fit to Bessel function for *f* = 2.5 to 12Hz.
b) SWV profile at *KPK* from SPAC analysis: 1m of filling, 17m of alluvial sediments (clay and silt), 110m to 230m of low-velocity sand from Tertiary. Bedrock interface not resolved from SPAC alone; but with help of observed HVSR and gravity survey. Solid line is best–fit SWV model, dashed line is alternate SWV model.
c) Periods of resonance (T_h) from HVSR, R_0 and site amplification from strong ground motion analysis. Grey rectangles outline T_h from observed HVSR.

c) Resonance & Site Amplification – *KPK*



Discussion

GUN

Periods of resonance on observed HVSR and modelled R_0 agree well at *GUN* (Table 1). This suggests the hypothesis of a layered earth model is valid. Period of resonance is shifted to longer period for strong ground motion analysis. We suggest this shift is due to the input of damping and modulus reduction factors in strong ground motion modelling. This was also observed in Asten *et al.* (2002), using model defined in Lam *et al.* (2001). Strong ground motion modelling with elastic parameters agrees well with observed HVSR (not presented).

KPK

Periods of resonance (T_{h1}=0.50s) on observed HVSR and modelled R_0 agree well at *KPK,* and is interpreted as the interface between the Quaternary alluvial sediments and the Tertiary sediments. Period of resonance (T_{h2}=1.10s) on observed HVSR is shifted to longer period (2.00s) on modelled R_0. We postulate the presence of 2D effects from the Tamar valley in the resonance pattern, shifting HVSR peak to shorter period (Bard and Bouchon, 1985). Both T_{h1}=0.50s and T_{h2}=1.10s on HVSR are shifted to longer period (0.70s; 3.00s) on strong ground motion analysis, due to the use of non-elastic parameters in strong ground motion analysis and 2D effects from the Tamar valley.

Table 1. Periods of Resonance at Sites *GUN* and *KPK*

SITE	T_h	Observed HVSR	Modelled Ellipticity	Modelled Strong Ground Motion
GUN	T_h	0.90 sec	0.90 sec	~ 1.30 sec
KPK	T_{h1}	0.50 sec	0.51 sec	0.70 sec
KPK	T_{h2}	1.10 sec	2.00 sec	~3.00 sec

We conclude that SPAC and HVSR microtremor survey methods can be used conjointly to analyse the resonance pattern induced by low velocity sediments over hard bedrock. Strong ground motion analysis adds valuable information concerning the use of elastic or non-elastic parameters in the modelling process.

- Asten, M.W., Lam, N., Gibson, G., and Wilson, J. (2002), Microtremor survey design optimised for application to site amplification and resonance modelling: In *Total Risk Management in the Privatised Era*, Proceedings of Conference, Australian Earthquake Engineering Society, Adelaide, Paper 7.
- Bard, P-Y., and Bouchon, M. (1985), The two-dimensional resonance of sediment-filled valleys: *Bulletin of the Seismological Society of America* **75**, No.2, 519-541.
- Hermann, R. (2002), Computer programs in seismology: An overview of synthetic seismogram computation, version 3.30, 2002 edition, Saint-Louis University, USA.
- Lam, N.T.K., Wilson, J.L., and Chandler, A.M. (2001), Seismic displacement response spectrum estimated from the frame analogy soil amplification model: *Engineering Structures* **23**, 1437-1452.
- Leaman, D. (1994), Assessment of gravity survey, City of Launceston: *Technical Report for Launceston City Corporation Seismic Zonation Study*, Leaman Geophysics, Hobart, Tasmania.
- Robinson, D., Dhu, T., and Schneider, J. (2006), SUA: A computer program to compute regolith site-response and estimate uncertainty for probabilistic seismic hazard analyses: *Computer & Geosciences* **32**, 109-123.