A Combined Active and Passive Seismic Methods To Characterize Strong-motion Sites in Western Washington, U.S.

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INTRODUCTION

- Knowledge of the **shear-wave velocity profile** at strong-motion station sites is important for **calibrating accelerograms** in terms of **local site effects.**
- **Surface-wave seismic prospecting** methods provide an effective tool for an **inexpensive** and **deep penetrating** seismic characterization of subsoil.
- We used a **combination of active** (Multi-channel Analysis of Surface Waves, **MASW**) **and passive** (Extended Spectral AutoCorrelation, **ESAC**) array techniques along with the single-station ambient vibration measurements (Horizontal-to-Vertical Spectral Ratios, **HVSR**) to characterize strong-motion sites.
- As a whole, we studied 18 strong-motion sites: 10 located in Washington state and 8 in Oregon state.

METHODOLOGY

1. Retrieval of available information

Geological surveys, boreholes, water wells.

2. Exploratory survey

Seismic survey by single-station ambient vibration measurements (**HVSR** analysis) aimed at estimating **resonance frequency** value, f_0, at the site. For practical reason, it is not always possible locating seismic arrays in the exact correspondence of the strong-motion station. In these cases, the comparison of HVSR curves at the strong-motion station and at the array site allows evaluating the actual correspondence of subsoil structure at the station and at the array site.

3. Array seismic survey

We used a combination of active (MASW) and passive (ESAC) array techniques to characterize strong-motion sites by the reconstruction of the surface waves dispersion curves at the considered sites. The **MASW** analysis allows a better reconstruction of the dispersion curves for highest frequencies (at and above 10 Hz) by supplying a good constrain for the shallowest part of the Vs profile (up to 30 m). ESAC methodology allows definition of the low frequency segment of the dispersion curve (4-10 Hz) allowing to constrain the Vs profile at larger depth (80- 100 m).

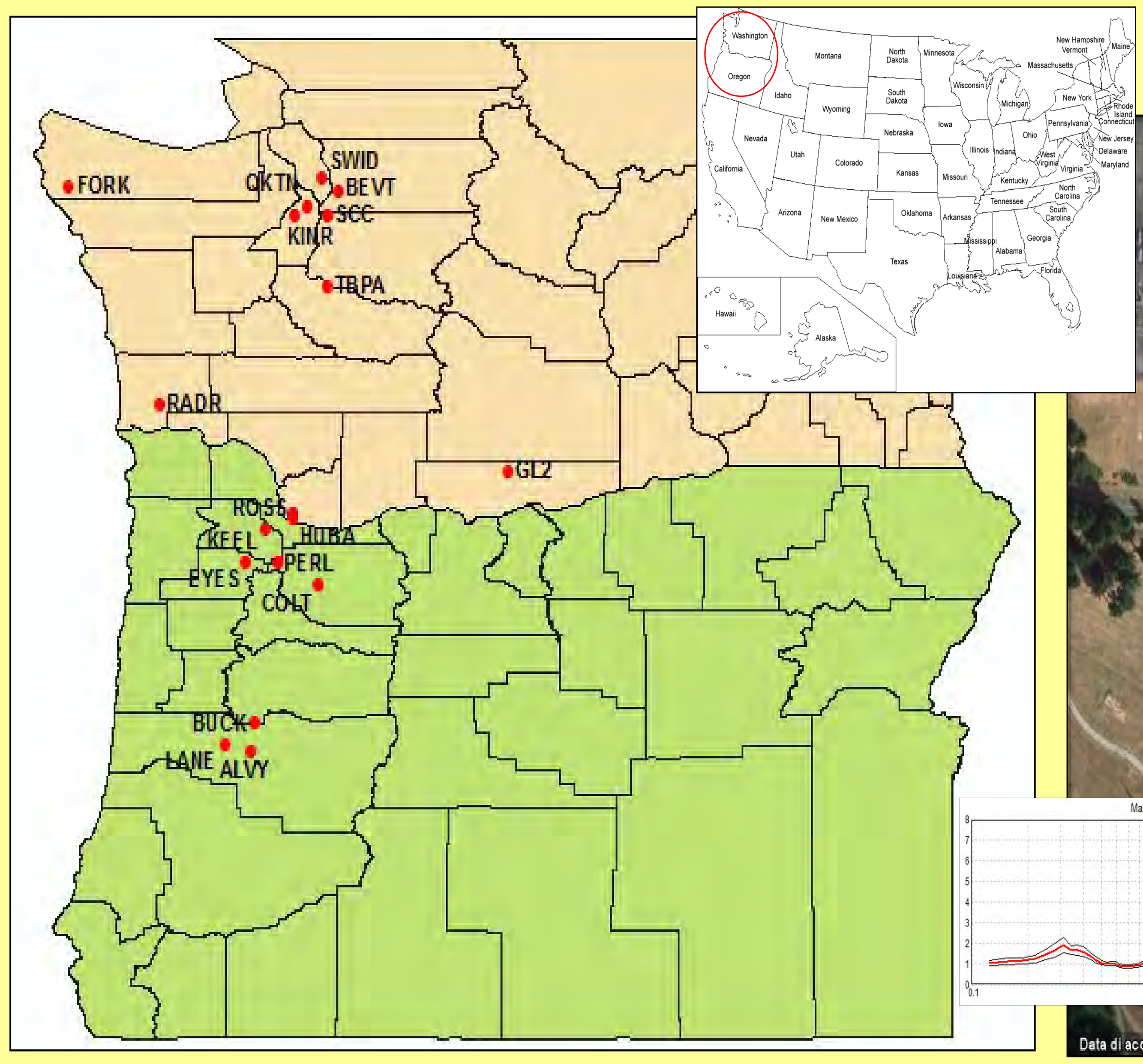
4. V_S profile by joint inversions

The Rayleigh waves dispersion and the HVSR curves were jointly inverted to providethe local Vs profile. To this purpose, V_S profile is reconstructed **by a combined use of these data** in the frame of a global-search inversion algorithm (**Genetic Algorithm**) . This processing allows us to manage the **extreme non-linearity** of the inverse problem and **mitigate** problems associated with the **non-uniqueness** of the solution. A **strict synergy** between geologic surveys, boreholes (when available) and seismic surveys allows a further **reduction of** relevant **uncertainties**.

MAIN RESULTS

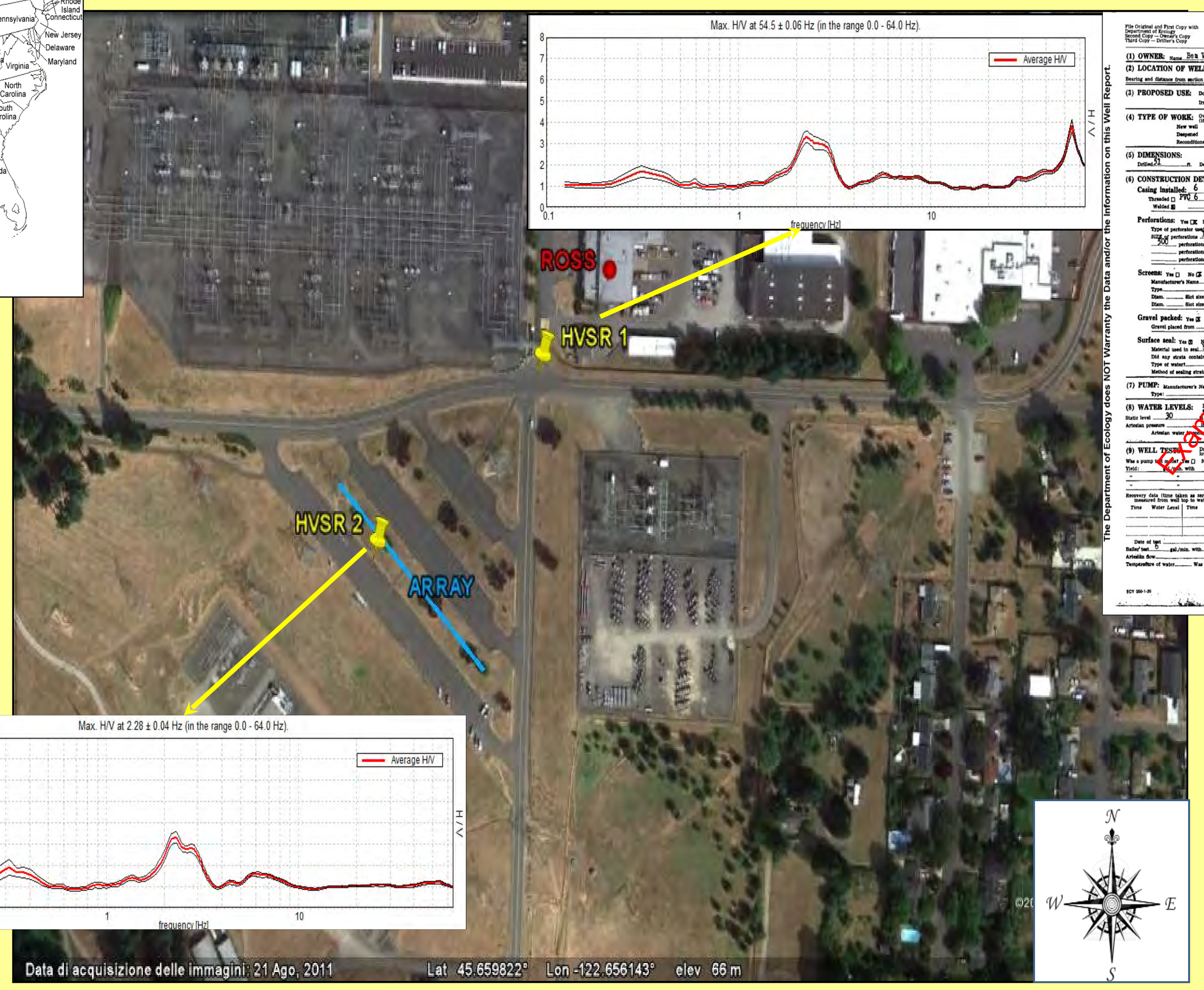
SITE	V_{30} (m/s)	NEHRP soil class	Resonant layer depth (m)	Average velocity to resonant layer (m/s)	f_0 (Hz)
SCC	500	C	gradual increase in velocity with depth	-	flat
BEVT	600	C	gradual increase in velocity with depth	-	flat
RADR	485	C	14	680	8
KINR	300	D	370	750	0.5
TBPA	375	C	260	630	0.6
QKTN	545	C	460	670	0.3
FORK	330	D	4	160	12
SWID	530	C	420	680	0.4
GL2	520	C	55	610	2.5
ROSS	300	D	43	340	2.3
HUBA	375	C	48	410	2.5
PERL	340	D	36	320	2.3
COLT	550	C	16	480	7
KEEL	250	D	120	360	0.7
EYES	375	C	14	230	3.2
BUCK	1200	B	gradual increase in velocity with depth	-	flat
ALVY	780	B	gradual increase in velocity with depth	-	flat
LANE	750	C	gradual increase in velocity with depth	-	flat

STRONG MOTION SITE LOCATIONS

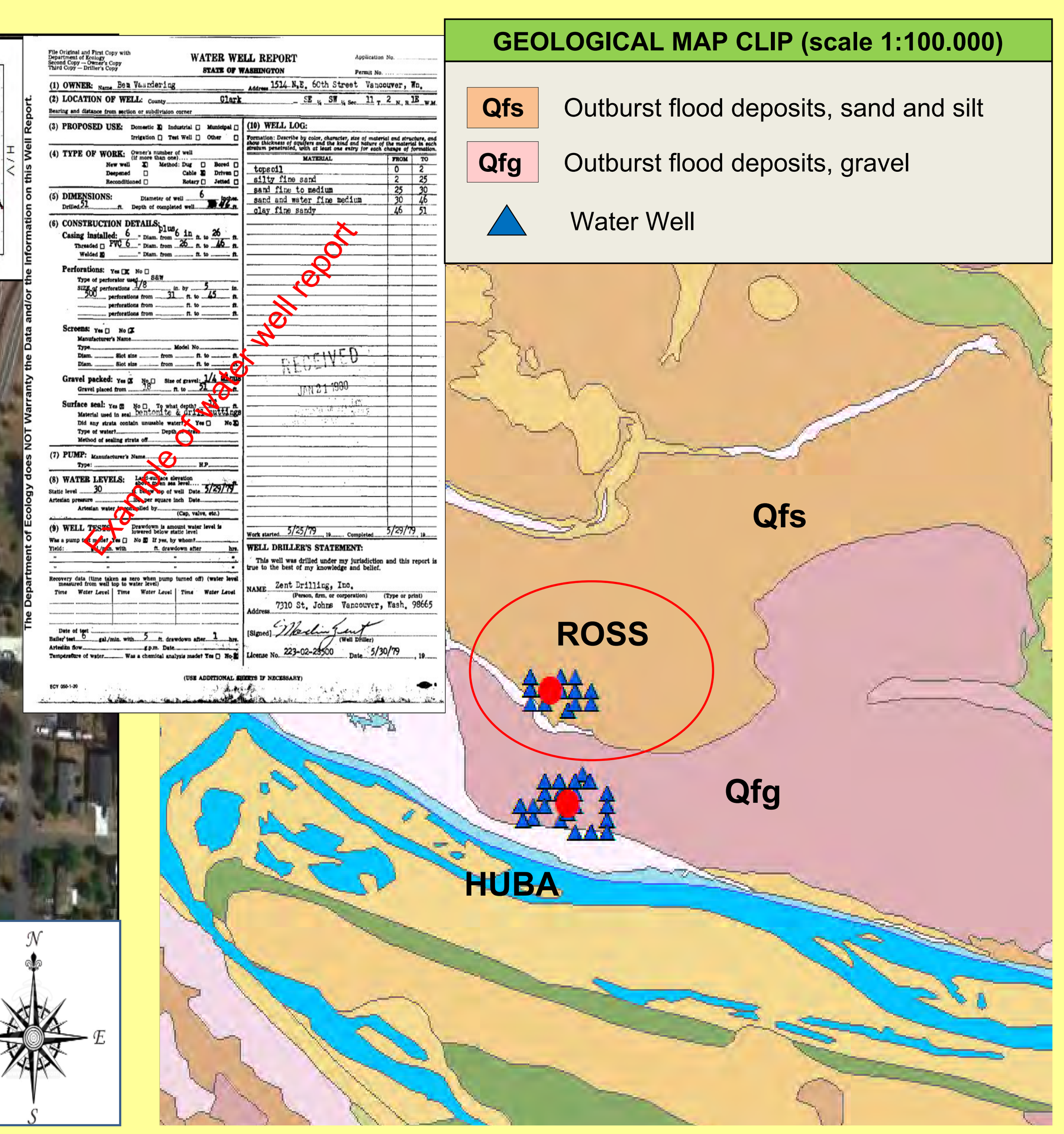


METHODOLOGY APPLICATION TO "ROSS" STATION

Exploratory Survey



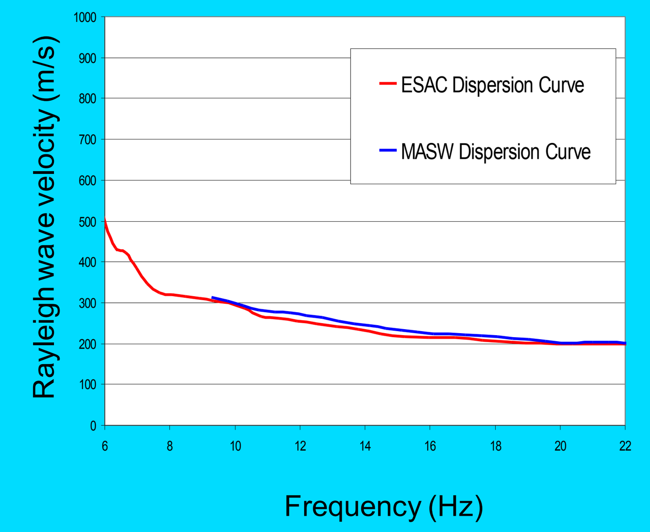
Available Information

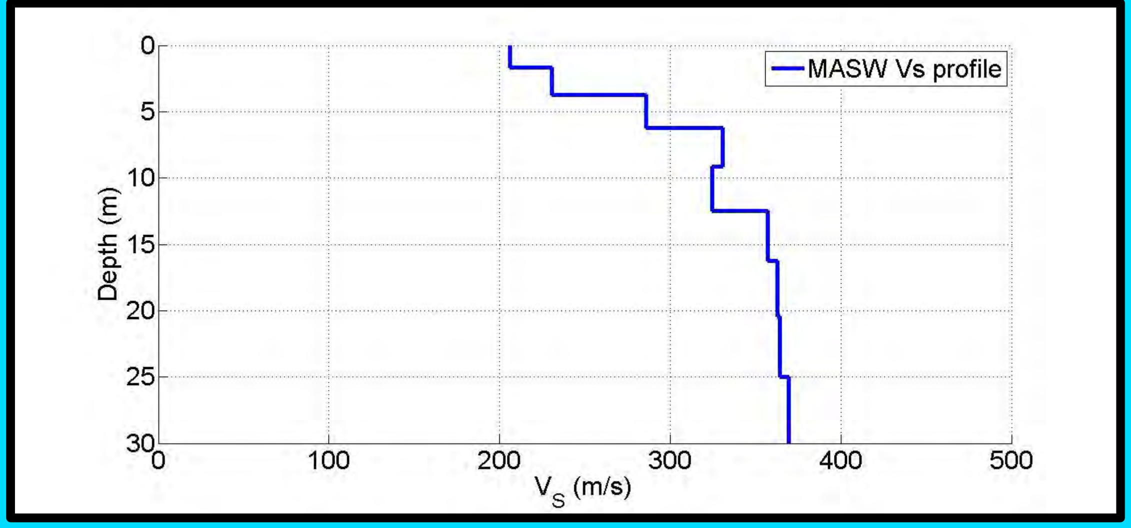


"ROSS" STATION: Vs profile by joint inversion

MASW RESULT

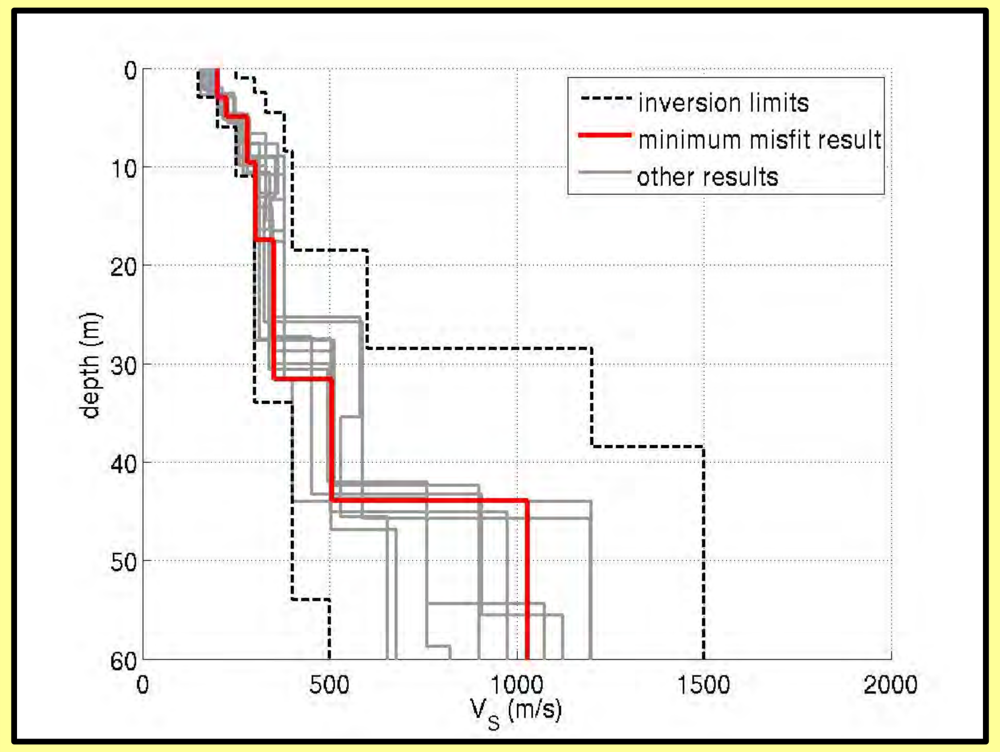
A prelimnary inversion of the better constrained high frequency segment of the dispersion curve was carried on firstly to constrain the shallowest part of the Vs profile (<30m). Then the whole dispersion and HVSR curves were jointly inverted by considering geological information and preliminary inversion results to limit the search space.This procedure allows a prolongation ot depth of the Vs profile up to several tens of meters.



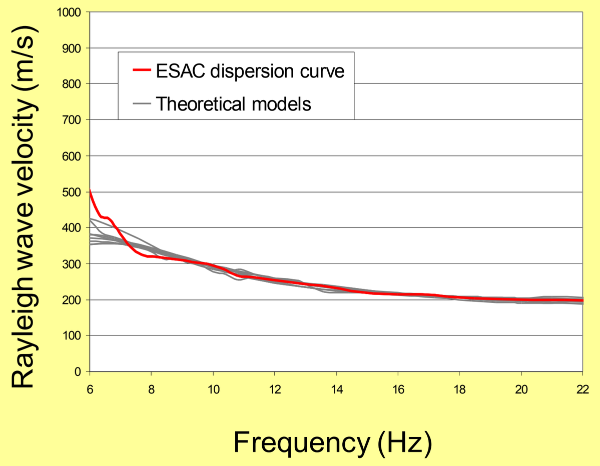


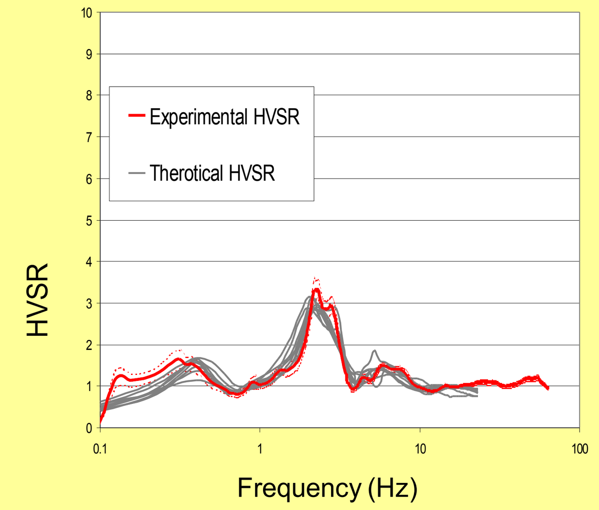
Ten joint inversions by ambient vibration data were performed

V_s profiles calculated in the frame of a global-search inversion algorithm (Genetic Algorithm). In red is shown the profile characterized by a minimum misfit



Correlations between experimental and theoretical curves





CONCLUSIONS

1. This combined use of active (MASW) and passive (ESAC, HVSR) methods is a practical inexpensive and fast way to reconstruct the Vs profile at strong-motion sites.

2. Local geology and/or borehole information was combined to better costrain the inversion and to reduce the uncertainty in velocity profiles

3. Joint inversion of dispersion and HVSR curves provide share-wave velocities at depths of the order of tens to hundred meters of depth.

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