Development of Vs30 and Isoperiod Map for Metropolitan Lima

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Introduction

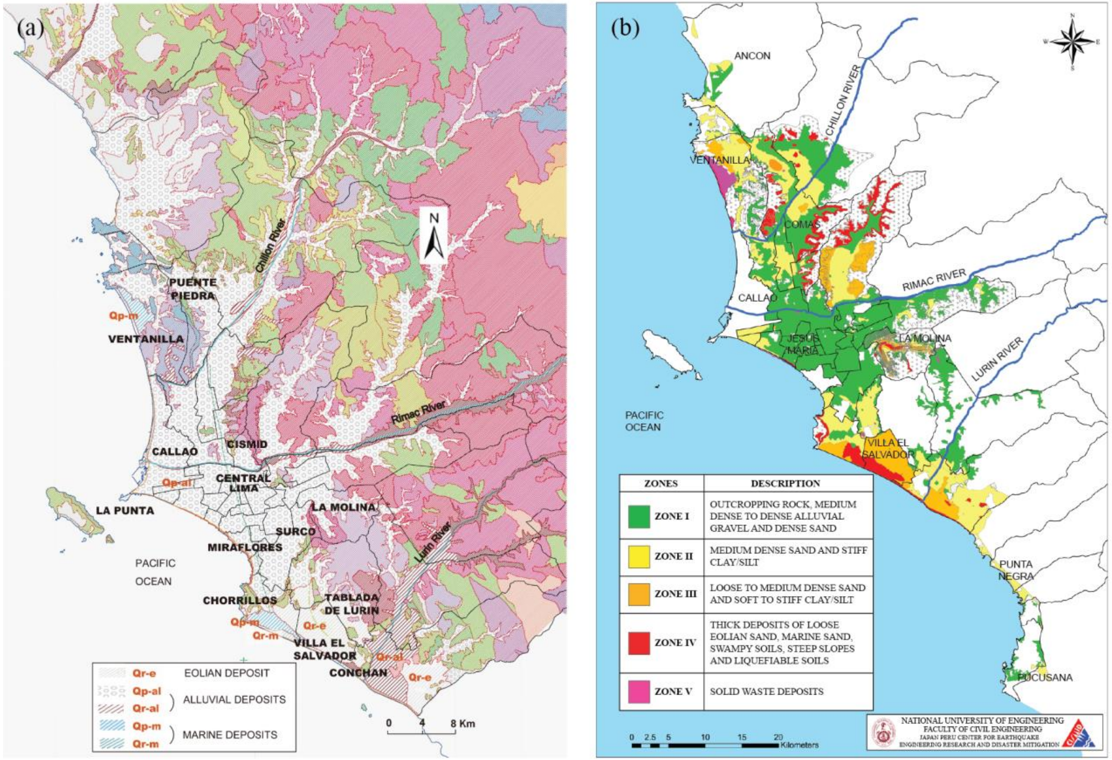


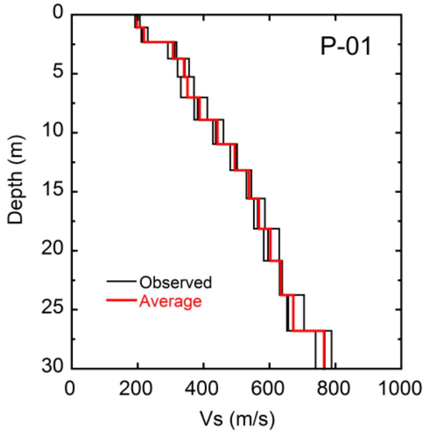
Fig. 1. (a) Geological map, (b) Soil distribution map of Metropolitan Lima

Lima, the capital of Peru, is located in the west-central part of the country and is divided into 50 districts.

Regarding its soil type distribution and geomorphology, the city can be basically understood as a consequence of the **erosional process caused by three main rivers**: Chillon, Rimac and Lurin. Thus, the majority of the metropolitan area is built over the alluvial materials originated by the transportation of **gravel**, with boulders of medium size, along with sandy and silty-clayey lens within these deposits. In addition, **eolian and marine materials** can be encountered in the northern, southern and western regions of the city, as well as isolated areas of organic soil.

Geophysical Tests

24-channel OYO Corporation MASW equipment



Tokyo Sokushin CV-374AV2 sensors

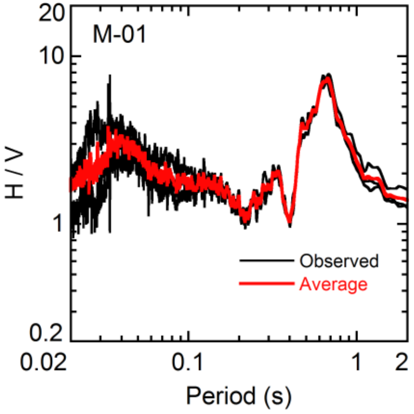


Fig. 2. (top) MASW test and resulting Vs profile, (bottom) Microtremor single point measurement and its corresponding H/V spectrum

A first seismic microzoning study was implemented in 2004 by CISMID, which mainly included mechanical (soil pits, DPL and SPT tests) and dynamic (microtremor single point measurements) information obtained throughout the city.

Since 2010, constant revisions of the Microzoning Maps were conducted in order to redefine the transition of zones with different seismic classification. Thus, a more dense distribution of the aforementioned tests was considered, in addition to the implementation of Multichannel Analysis of Surface Waves (**MASW**) tests and **microtremor array measurements**.

As a result, a better understanding of the dynamic characteristics of the underlying soil deposits was possible by means of the estimation of the average of the shear-wave velocity in the first 30 m (**Vs30**) and the **fundamental period** of vibration as the peak value of the **horizontal-to-vertical (H/V) spectrum** of ambient vibrations.

Vs30 Map

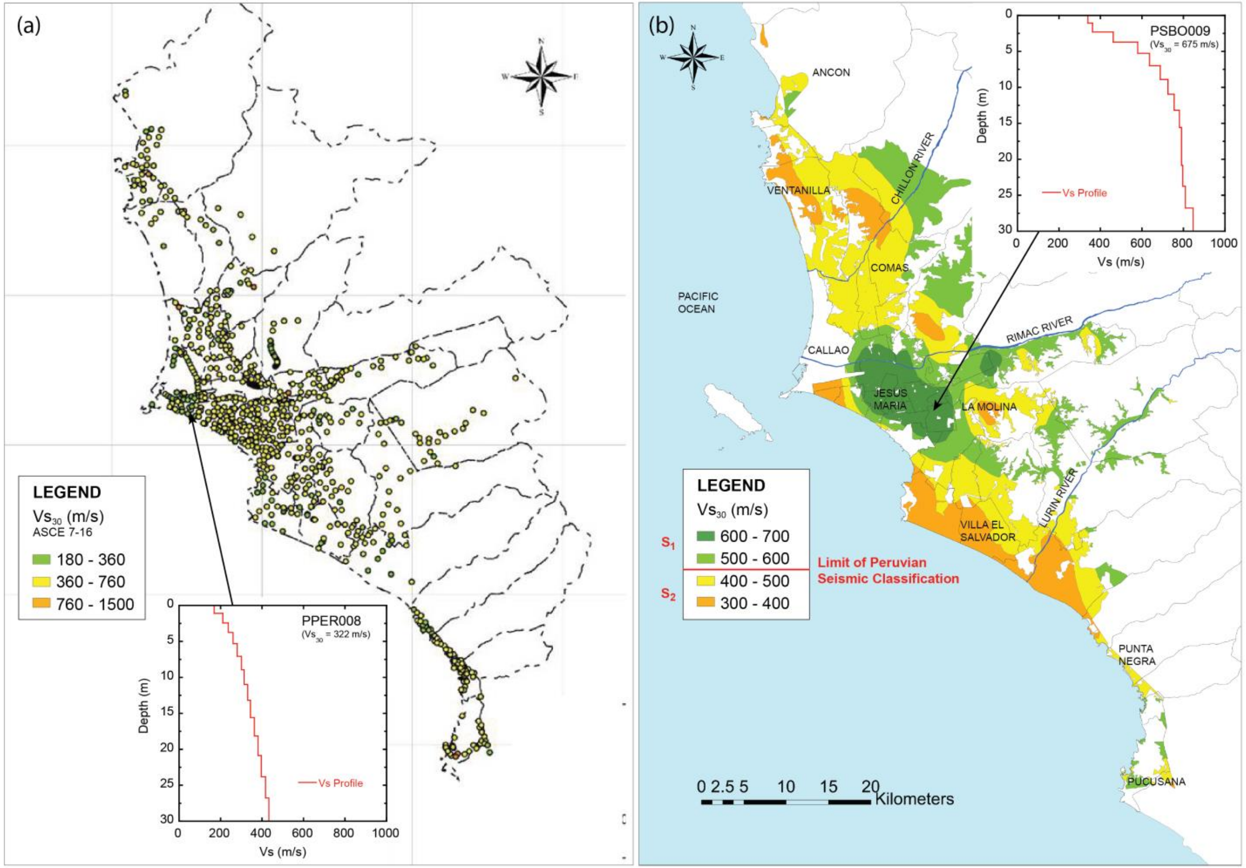


Fig. 3. (a) Distribution of Vs profiles, (b) Vs30 map for Metropolitan Lima

CISMID's database of Vs profiles comprises the results of approximately **800 MASW** tests carried out throughout Metropolitan Lima.

As expected, the stiffest region (Vs_{30} > 600 m/s) is concentrated in the **central part** of the city as a consequence of the **alluvial fan of the Rimac river**. High values of Vs30 are also found towards the **upstream direction** of the three main rivers that cross the city.

Areas with the lowest values of Vs30 (< 300 m/s) are located in the northern and southern regions of the capital, coinciding with the presence of **eolian sandy deposits**.

Isoperiods Map

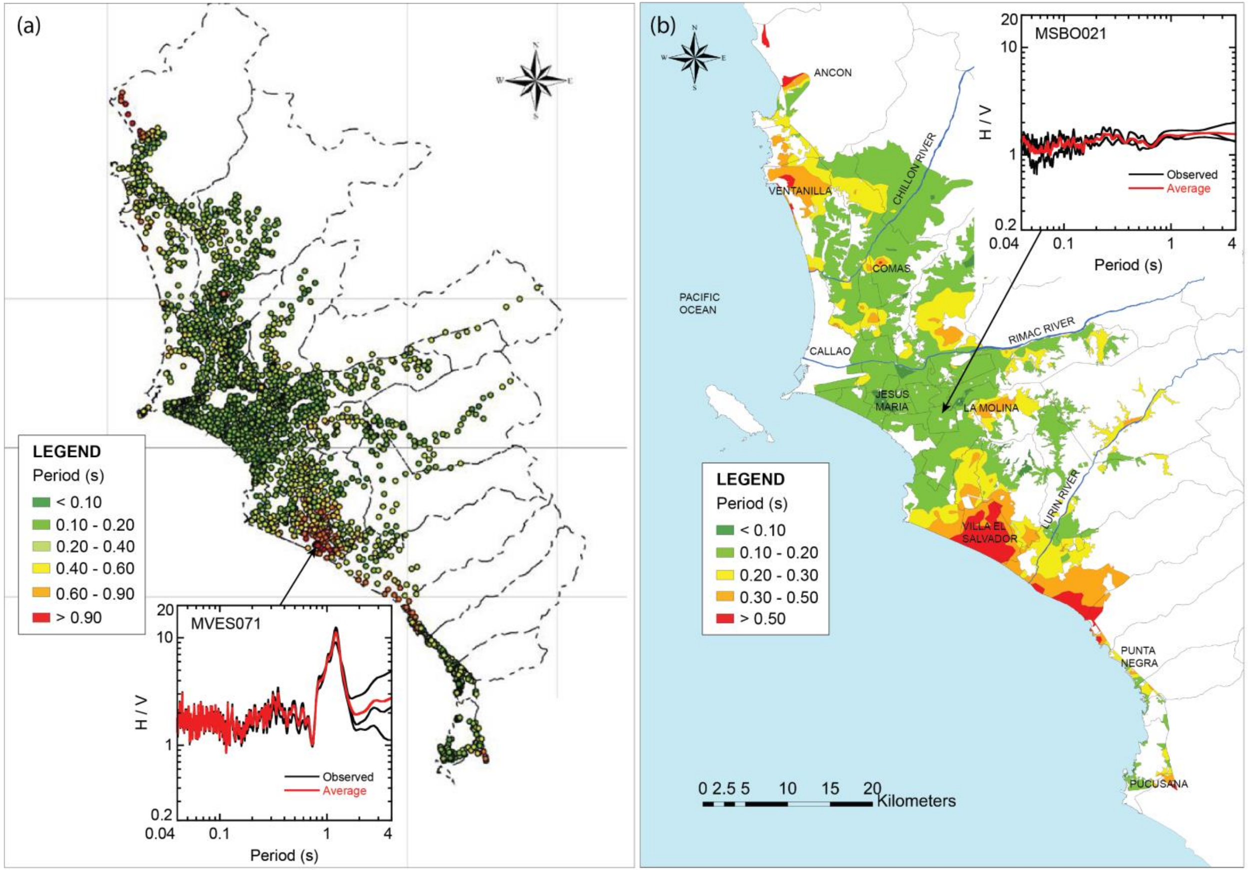


Fig. 4. (a) Distribution of microtremor single point measurements, (b) Isoperiod map for Metropolitan Lima

Regarding the values of fundamental period, CISMID's database is comprised of approximately **2000 microtremor single point measurements**.

H/V spectra have either a **sharp peak in very short periods or a flat shape** in the **central part** of the city, in coincidence with large values of Vs_{30}, and in the **rocky outcrops** in the lowlands of the Andean foothills.

Longer periods are concentrated, in a similar pattern to the Vs_{30} distribution, in the northern a southern regions of the city. Some measurements located at the crest of sandy dunes **reached values as long as 1 s** with an evident peak that might be a consequence of the **impedance ratio of the deeper part of the soil substructure**.

Concluding Remarks

During the last ten years, CISMID has been collecting and generating relevant information regarding the dynamic behavior of the underlying soil deposits in Metropolitan Lima. In the form of shear-wave velocity profiles and fundamental periods of vibration, it was possible to estimate a **Vs30** and **Isoperiods Map** for Lima city, in which a major distribution of **stiff materials** is evident as a result of its geomorphological origin. The stiffness of the soil deposits **decays towards the outskirts of the city**, coinciding with the eolian formations and the mouths of the three main rivers that cross the city.

It should be pointed out that, in the current issue of the Peruvian Seismic Code (E030-2018), seismic classification of a specific soil deposit is based on its value of **Vs30 only**. It is important to start contemplating the inclusion of **additional parameters**, such as the **fundamental period of vibration** obtained from microtremor single point measurements, since, even if it is estimated from ambient vibrations, it might be an adequate indicator of the behaviour of the deposit under larger amplitude solicitations and, intrinsically, includes the **effect of layers deeper than the first 30 m** in the overall dynamic response.
Empirical evidences were found by means of the signal processing of seismic records in accelerometers installed in Metropolitan Lima for two important far-field earthquakes (Pisco-2007, Lagunas-2019).

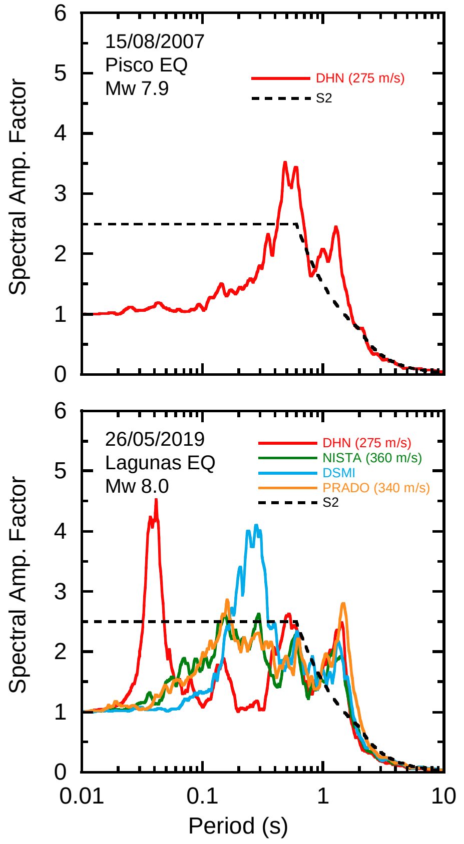


Fig. 5. Normalized response spectra for seismic stations with S2 classification for two recent earthquakes. Values in parenthesis are their corresponding Vs30