Seismic noise measurements along the slope of the L'Aquila terrace

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Sessione 22

Natural Hazards – E11. From L'Aquila to Emilia: Comparison of seismic microzonation experiences

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Aim:
- To investigate the variation of site effects along the flanks of the L'Aquila terrace
- Role of the topographic effects ??
- Effect of the caves ??

Observation:
- L'Aquila downtown is built on the top of a hill characterized by steep slopes toward the Aterno River Valley
- Many collapses and strong damages on buildings (including “Casa dello Studente”) were observed in proximity of the slopes (southern edge of the downtown) during the 2009 L'Aquila earthquake

Method of analysis:
- Ambient noise analysis (HVSR)
- Aftershock data
- Numerical modeling (in progress)
This area is very close to the lithological contact between the alluvial sediments of the Aterno Valley and the conglomerates (Megabrecce) on which L'Aquila downtown is settled, and coincides with a remarkable morphological slope. Moreover the same area was the site of large embankments in the first decades of 1900. Thus this geomorphologic feature can be considered as a probable factor that increased the damage....” from Tertulliani et al., 2011

The downtown is settled on a calcareous terrace, mainly composed of a Pleistocene stiff calcareous breccia over-imposed to ancient lacustrine sediments.

The upper portion of the L'Aquila breccia is irregularly affected by the presence of residual soft soils known as "red soils" or filling material.

The shear-wave velocity profile is characterized by a velocity inversion at a depth ranging from few tens up to one hundred meters (contact between Breccia and Lacustrine deposits).
Symbols: ambient noise measurements located considering also the available investigations (boreholes and Vs data)

Seismic equipment

Topographic amplifications factors (Italian Building Code NTC08)

<table>
<thead>
<tr>
<th>Topographic class</th>
<th>Description</th>
<th>Amplification factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Flat surface; isolated slopes and cliffs with average slope angle $i &lt; 15^\circ$</td>
<td>1</td>
</tr>
<tr>
<td>T2</td>
<td>Slopes with $i &gt; 15^\circ$</td>
<td>1.2</td>
</tr>
<tr>
<td>T3</td>
<td>Ridges with crest width significantly less than the base width and $15^\circ &lt; i &lt; 30^\circ$</td>
<td>1.2</td>
</tr>
<tr>
<td>T4</td>
<td>Ridges with crest width significantly less than the base width and $i &gt; 30^\circ$</td>
<td>1.4</td>
</tr>
</tbody>
</table>
Filling material
Red soils
Calcarenous breccias
Lacustrine deposits
Calcarenous breccias

Vs profiles by seismic dilatometer test

f = Vs/4H ~ 500/(4·20) ~ 6Hz
Summary

- From top (cave)
- Inside cave
- Giacomo house
- Giacomo house bis
- Via A. Diaz

- Porta Bagno
- Near Aterno valley
- Aterno valley crosshole
- Aterno valley bottom of the hill
Noise Transect “Fosso Porta di Bagno”

Shift of the spectral minimum of the vertical component down.

Dashed curves: bottom
Continuous curves: top

Horizontal components

Red: r06, blue: r09 (aterno valley)

Spectra amplitudes

Frequency (Hz)
The noise measurements at the base of the hill show a broader peak and a lower amplitude in comparison with the measurements at the top.
Shift of the spectral minimum of the vertical component

**Porta Napoli**

- sc04 vs sc01
- top vs bottom
- Continuous vs dashed

**H/V**

- Shift of the spectral minimum of the vertical component

**Horizontal component**

- green: NS
- red: EW
- blue: UP

**Frequency (Hz)**

- 0.2, 0.4, 0.6, 0.8, 1, 2, 4, 6, 8, 10

**Spectral amplitude**

- 0, 20000, 40000, 60000

**Azimuth (degrees)**

- 0, 20, 40, 60, 80, 160, 180

**H/V amplitude**

- 0, 2, 4, 6
AQ13, AQ09 and AQ04 recorded many aftershocks of the L'Aquila sequence

Milana et al. (2011)
The contribution of seismic data in microzonation studies for downtown L'Aquila, Bull. Earth. Engin. 9(3) 741-759.

Idrogeologia della conca aquilana.
Pubbl. DISAT, Università dell’Aquila, 92/6, 28 pp.
Transect Borgo Rivera/Santa Chiara/Casa dello Studente

- Top (Casa dello studente)
- H/V
- Down (Borgo Rivera)
HV noise

Top (Casa dello studente)

HV computed on about 250 aftershocks (AQ13 and AQ09 situated in proximity of the Aterno River Valley; AQ04 nearby Casa dello Studente)

M 2.4, 30 May 2009, Compon. Z

Standard Spectral ratios (Roio site as reference site)
Measurements in caves (Breccias)

r12: inside cave
r11: top cave (Casa dello studente)

r12bis: just outside cave
r12: inside the cave
r12bis: just outside cave
r12: inside the cave
Measurements in caves (Breccias)

**r11**: top cave (Casa dello studente)

**r12**: inside cave

**r12bis**: just outside the cave

- Blue: vertical
- Green: NS
- Red: EW
Measurements in caves (Breccias)
<table>
<thead>
<tr>
<th>Thickness</th>
<th>Unit</th>
<th>Vp (m/s)</th>
<th>Vs (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80+50 m</td>
<td>breccia</td>
<td>2000</td>
<td>1000</td>
</tr>
<tr>
<td>120 m</td>
<td>lacustrine deposit</td>
<td>1500</td>
<td>750</td>
</tr>
<tr>
<td>500 m</td>
<td>basement</td>
<td>4500</td>
<td>2250</td>
</tr>
</tbody>
</table>

2D Numerical modelings are in progress to understand the role of topography on ground shaking.
Conclusions:

- Because the variation of the spectral minimum of the vertical component, the noise H/V ratios at the bottom show a broader peak with lower amplitudes in comparison with the H/V curves at the top.

- The H/V ratios computed on earthquakes seem to show the same behaviour of those computed on noise, although the differences between top and bottom are less clear.

- The investigated caves cannot be recognized by noise measurements, likely related to the relative small dimensions and to the thickness (> 15 m) between the cave roof and the topographic surface.

- The low-frequency resonance shows a N120°/N160° polarization. This direction is parallel to the main elongation of the Aterno River Valley and/or perpendicular to the main elongation of the L'Aquila hill.
Transetto Collemaggio-Orto botanico

cm07 (top)

cm11 (down)