Geophysical data interpretation of *Passo della Morte* Landslide: Eastern Italian Alps

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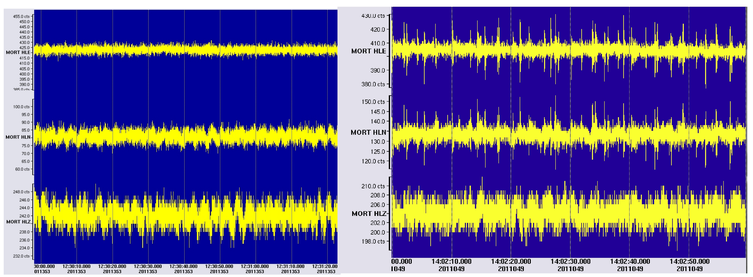
Abstract

The Passo della Morte block-slide covers a relative large area in the Carnic Alps, along the left side of the Tagliamento River, between Forni di Sotto and Ampezzo (Eastern Italian Alps). The peculiar characteristics of the area (high seismicity, presence of important infrastructures and a river) increase the risk of this place. This study concentrates on the western part of the Deep Seated Gravitational Slope Deformation (DSGSD), focusing on the potential instability of the rock slope crossed by road tunnels and on its connection with the DSGSD activity.
The main aim of this work is: monitoring the seismic activity generated by slope deformation, studying seismic site effect and directivity in seismic site response and defining the stratigraphic and geological characteristics of involved materials.
The microseismic activity recorded by a short-period seismometer, installed inside the tunnel, has been analyzed. A direct relation between precipitation and the high frequency microseismic activity has been found out.
The seismic site effects and the directivity in seismic site response of the rock mass were investigated through Nakamura (1989) method and Fäh technique (2003). All three sites have shown a clear evidence of polarization of seismic energy in the direction of N/NW-S/SE and E/NE-W/SW, compatible with the slope geometry, to the direction of slope inclination, and with the stratification direction of the limestone outcropping in this area.
The GPR investigation was useful to identify both vertical and lateral variations of the lithotypes and different degrees of rock fracturing and fluid content. Instead, the seismic investigations allowed to identify a main refraction and to determine the propagation velocity of compressional and shear waves of the two layers found.

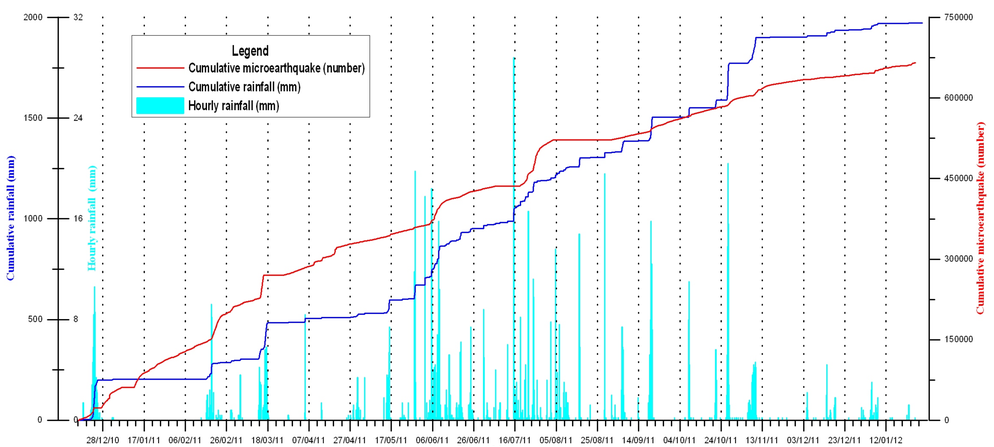
Microseismic activity monitoring

Location of the seismic station (MORT) and a detail of the instrumentation



An example of one minute of seismic station recording in a dry day (on the left) and a rainy one (on the right)

The graph reports the cumulative curve of microseisms number and rainfall. A direct relation between rainfall and microseisms has been found. A delay variable from several hours to almost a day, between precipitations and the corresponding increase of microseisms, is recognized.



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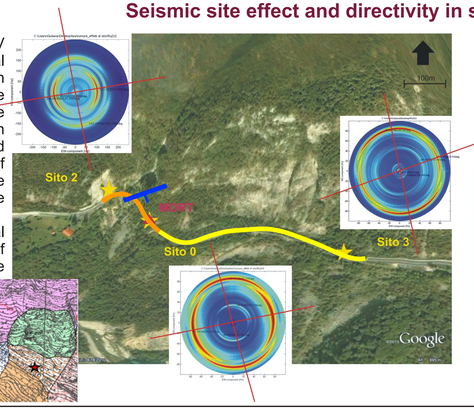
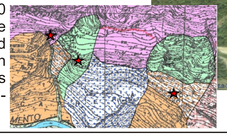
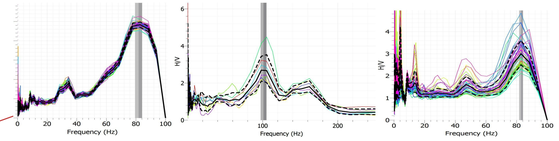
Seismic site effect and directivity in seismic site response

In the figure are plotted the H/V spectral ratio in the horizontal plane as a function of azimuth (Fäh technique, 2003) for three sites on the landslide. The polarization directions of main peaks are highlighted with red segment. The stratification of limestone outcropping in the studied area is represented by the blue line.
Below is reported the geological map of the area with the location of the three sites. Site 2 on dolomite (pink), site 0 on limestone (green) and site 3 on debris (white-orange).







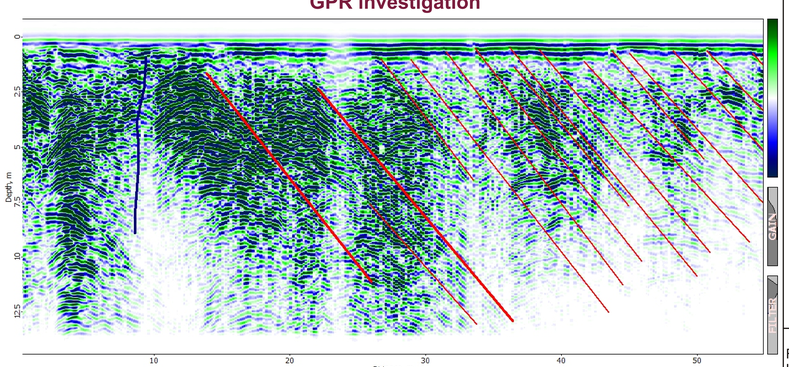
	Frequency (Hz)	Velocity (m/s)	Substrate depth (m)
Site 0	80	1500	5
	35	1500	11
Site 2	100	1500	4
	150	1500	3
Site 3	85	400	1
	5	400	20
	10	400	11
	50	400	2

Curve of the H/V spectral ratio for the three sites. The table reports the results of the application of the law:

$$H = Vs/4f$$

to the frequencies obtained by the H/V ratio. H is layer thickness, Vs is shear wave velocity and f is frequency. The velocities used in the site 0 and site 2 are obtained by the active seismic investigation (see below).
The thickness obtained at the site 3, for 5Hz frequency, has been confirmed by an existing borehole few meters away.

GPR investigation



Detail of a GPR section carried out inside the road tunnel (orange and yellow lines on the map above). The stratification of limestone is highlighted in red, different layers are clearly recognizable. White or light color areas are characterized by high attenuation of EM waves. The attenuation variability along the section probably highlights strong lateral variations due to different water contents within the rock mass. For instance, the attenuation area around the main discontinuity marked in blue, is probably due to the preferential water percolation within this zone.

Active seismic investigation

The table reports the results of the active seismic survey (refraction seismic) carried out inside the road tunnel that cross the studied area (orange and yellow lines on the map above).

Unit	Thickness	P velocity	S velocity
1	10m	2000m/s	1500m/s
2	-	4500m/s	2500m/s

Selected References

Fäh, D., Kind, F., and Giardini, D. (2001). A theoretical investigation of average H/V ratios, Geophys. J. Int. 145, 535-549.
Nakamura, Y. (1989). A method for dynamic characteristics estimation of subsurface using microtremor on the ground surface. Quart. Rep. Railway Tech. Res. Inst. (RTRI), 30, 25-33.

Acknowledgments

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