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Comparison of different techniques of ambient noise analysis to investigate slope response to seismic shaking in the peri-urban areas of Qiaozhuang (Sichuan, China)

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The 2008 Wenchuan earthquake reminded us once again that slope susceptibility to seismically induced landslides is a critical issue for civil protection. This is especially true in case of urbanised areas located at the foot of steep slopes, whose failures during an earthquake can heavily aggravate the threat to public safety. A thorough evaluation of seismic slope failure hazard and the planning of effective countermeasures should take into account the role that shaking amplifications can have in increasing susceptibility to mass movements. This can hardly be obtained via accelerometer monitoring of marginally stable slopes, which would require a prolonged employment of costly instrumentation on a large number of sites. Indeed, we know that seismic slope response can show sharp variations even within short distances.
The use of reconnaissance techniques based on the analysis of ambient noise, recorded for short time by portable lightweight instruments, offers an attractive alternative for wide-area investigation of slope dynamic response to seismic shaking. However, the application of standard techniques of noise analysis like the Nakamura's method (originally devised for sites characterised by flat surfaces and horizontal layering), can be of limited utility in the presence of high topographic relief and strong lateral lithological heterogeneities. This has recently led to the development of more advanced techniques aimed at a better exploitation of the informative potential of noise data in complex site conditions.
The case study of slopes impending over the urban area of Qiaozhuang (Sichuan, China) offered the possibility to test a new method of ambient noise analysis, named HVIP, which relies on the estimates of ellipticity of Rayleigh wave packets identified within noise recordings. We investigated three slope sites (Weigan Hill, Mount Dong and Mount Shizi), which experienced co-seismic failures during the 2008 Wenchuan earthquake. There seismic recordings acquired by a temporary accelerometer network provide data for the validation of the outcomes of ambient noise analyses. The comparison between the results of the Nakamura's and HVIP analysis with that of the seismic events recordings, showed that the new technique provides more stable and consistent results when measurements are repeated. Furthermore, HVIP technique is able to reveal site resonance properties that Nakamura's method fails to recognise in case of temporally variable disturbance caused by the overlapping, within the noise wave-field, of different type waves. The HVIP ambient noise analysis provided evidence of resonance phenomena acting at low frequency (∼1 Hz) at the scale of the entire relief (on Weigan Hill), of directional amplifications at intermediate frequencies (∼4 Hz) affecting ridge crests consisting of fractured rocks (on Mounts Dong and Shizi), and of higher frequency resonance (7-20 Hz) changing at very local scale. This represents valuable information for the collateral seismic hazard assessments in the Qiaozhuang peri-urban areas.