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Landslide investigation by means of different seismic methods , a case study in western Switzerland

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In Switzerland, landslides represent a major geologic hazard. Each year, landslides cause damages that affect civil engineering structures and have important financial consequences. Thorough understanding of failure type, sliding mechanism and cause of landslides is required to effectively mitigate their impact.

Typically, studies of landslides and slope instabilities make use of geotechnical, hydrological and GIS monitoring techniques. Geophysical surveys can help for better understand landslides: mainly by providing information on their internal structure. Electrical Resisitivity Tomography (ERT) and seismic refraction are the most frequently used geophysical methods on landslide. S- and P-wave reflection profiling has also been implemented.

We are seeking methods that are at the same time quick, efficient and easy to implement in a physical environment that is often difficult. With goal in mind, we used the seismic refraction technique together with seismic surface-wave dispersion analysis on the Ballaigues Landslide in western Switzerland

The Ballaigues Landslide was selected because of its shallow sliding surface at a depth of about 20 m. Moreover, previous ERT measurements as well as borehole information are available. The landslide is located at the foot of the Jura Mountains, in an area where the basement consists of limestones of Mesozoïc age that have been affected by folding and faulting.

Surface-wave profiles as well as seismic refraction profiles were acquired using 50 low frequency geophones and a 4.5 kg sledgehammer as a source.

The interpretation of the seismic refraction profile provides a four layer model. The first layer shows a velocity of 320 m/s and corresponds to top soil. Its thickness varies from 1 m to 5 m. The second and third layer show velocity in the range of 1250 to 1800 $m.s^{-1}$. They might be associated to the Quaternary deposits above the limestone basement.

The profile acquired on the upper part of the landslide shows layers with horizontal plane geometry. On this profile, basement with a velocity of 2200 to 3000 $m.s^{-1}$ is located at a depth of about 25 m. The seismic refraction profile acquired at lower part of the landslide reveals a glacial U-shape in the Mesozoic basement while Quaternary deposits reach a thickness of 35 m.

Rayleigh-wave dispersion curves were calculated in the 5-50Hz frequency range. The dispersion curves present a clear bimodal behaviour: below 30 Hz, the fundamental mode is carrying most of the energy while the first harmonic mode is the leading mode of propagation above 30 Hz. Inversion of the Rayleigh-wave dispersion curves provide a shear-wave velocity depth profile of four layers with velocities of 200 $m.s^{-1}$, 300 $m.s^{-1}$, 500 $m.s^{-1}$and 900 $m.s^{-1}$ to depths of 0,5, 12 and 27 m respectively.

Although the seismic refraction interpretation (P-wave velocities) and the surface-wave processing of the data (S-wave velocities) give the same number of layers, some discrepancies in the depth of layer boundaries are observe. Several factors such as water content, lateral heterogeneity of the medium and sliding surface depth, may account for differences between the P-wave and S-wave results.