Non-invasive and spatially continuous ground stability assessments using hybrid seismic surveying techniques

Preliminary surface seismic investigations for mapping geological faults and layering structures are an integral part of a well balanced general geotechnical construction site characterization programme.

Quantitative determinations of the geotechnical elasticity parameters of Young's ***E***-modulus, shear modulus ***G*** and Poisson's ratio ***ν***, are usually carried out either by laboratory analyses of rock samples extracted from boreholes or obtained from the results of borehole petrophysical wire line logging surveys. The above mentioned procedures have in common that they are

- cost-intensive, time consuming, and
- the findings derived cannot be regarded as in-situ values, since they are obtained from samples affected to a certain extent by the extracting (drilling) process.

Prevailing disadvantages

An additional drawback is to be seen in the fact that these values are, in the case of a single borehole, often recorded at non-representative locations. In the case of cross-hole seismic tomography surveys, with a separation of max. 30 m between the boreholes, only the vertical plane between them is analysed. In a larger and a more complex structured subsurface the costs for an area wide evaluation are unpredictable.

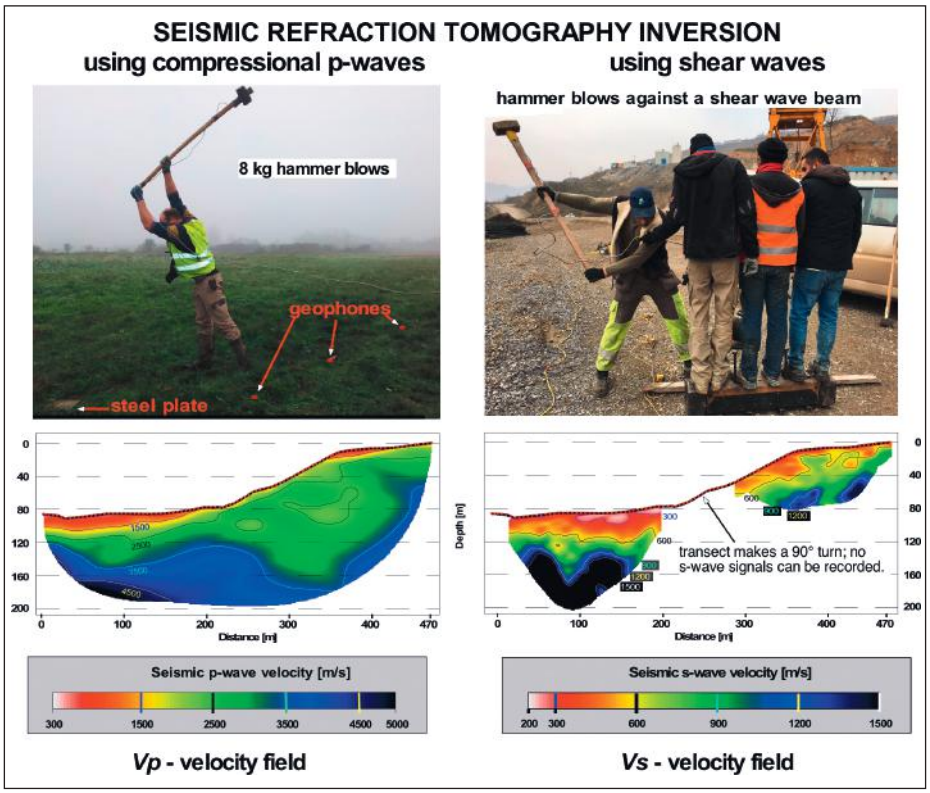
The dynamic elasticity moduli ***E, G,*** and ***ν*** are derived from the following measured values:

- The propagation velocity of compressional seismic waves ***Vp*** (between 300 and 6 000 m/s)
- The propagation velocity of shear seismic waves ***Vs*** (between 150 and 3 500 m/s)
- The rock/soil material density ρ (according to the locality; between 1.9 and 2.6 g(cm^3).

Higher score by using non-invasive probing methods

Considering that the ***Vp*** and ***Vs*** values are usually acquired in good data quality by using the non-invasive method of seismic refraction tomography and along continuous transects, the following advantages result:

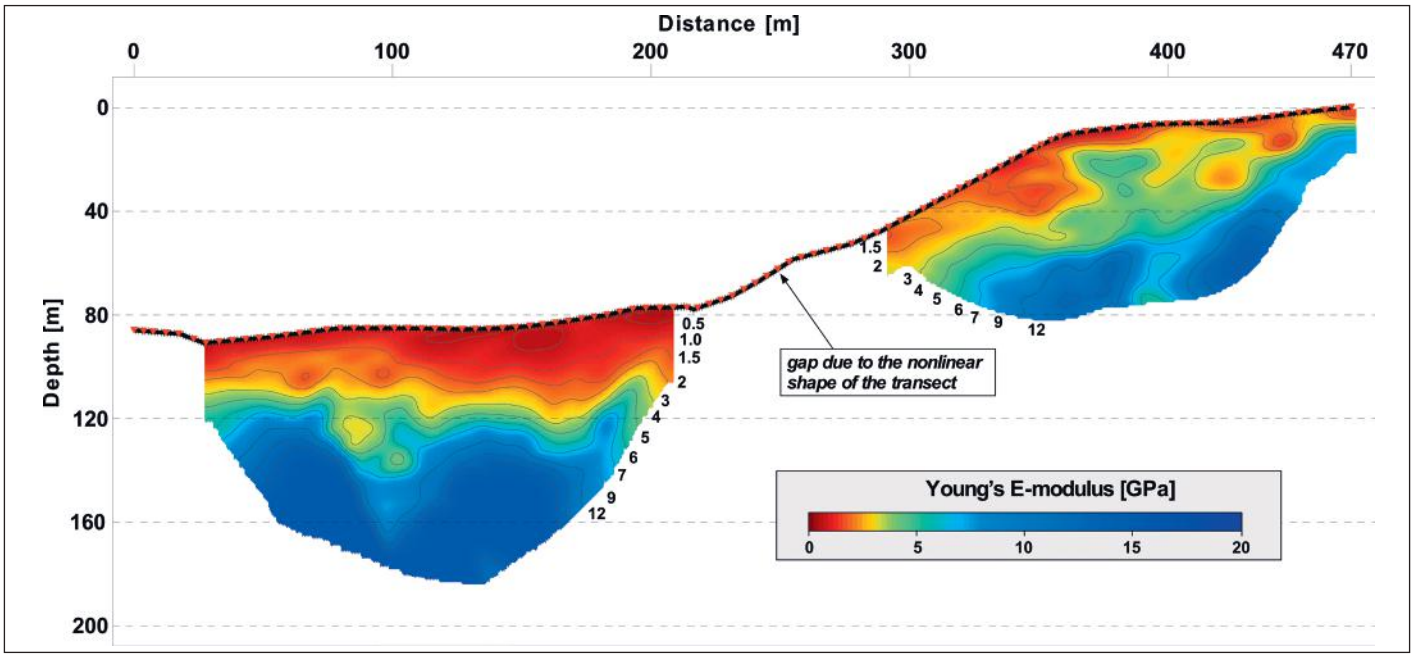
- Measured values are of the true in-situ type, since they have been recorded from an undisturbed environment.
- The ***Vp*** and ***Vs*** velocity fields contain the spatial distribution of these values **(s. Fig. 1).** In accordance with these, the dynamic elasticity parameters may be portrayed in spatially continuous depth sections.
- By using locally valid density values ρ (e.g. 1.9 until 2.6 g/cm^3), the dynamic elasticity values may be derived at a fraction of the costs for borehole and laboratory based probings. **Fig. 2** shows the distribution of the E-modulus values in a depth section.



Upper pictures: Seismic field data acquisition using vertical hammer blows onto a steel plate - horizontal blows against a wooden beam anchored to the ground. Lower pictures: Seismic velocity values derived down to depths in the order of 100 m!

Highest level of detail and additional pertinent information about the subsurface is obtained

The seismic field data acquired in the context of Vp refraction seismic tomography inversion are also amenable to reflection seismic evaluation procedures. Their result is comparable to an X-ray radiograph, since structural features of the subsurface are directly imaged in superior resolution not achieved by any other geophysical method.



Distribution of rock strength in the subsurface expressed by Young's E-modulus

The procedure of joint acquisition, processing und presentation of refraction and reflection seismic data – commonly denoted as hybrid seismic surveying – was introduced in 2000 by GeoExpert AG in Switzerland. The method has since then been continuously improved. One of these upgrades includes the derivation of the dynamic elasticity moduli, and in analogy to basic hybrid seismic surveying, the joint presentation of these as overlay onto the reflection seismic section **(s. Fig. 3)**.

Cornerstone in geophysical prospecting methodology

No other geophysical discipline provides in a joint image, as pictured in **Fig. 3**, both the structural features of the subsurface together with the distribution of the rock/soil rigidity parameters. In medicine this would be equivalent to an X-ray radiograph showing not only the ramifications of a cancerous tumor but also its degree of malignancy. ▼

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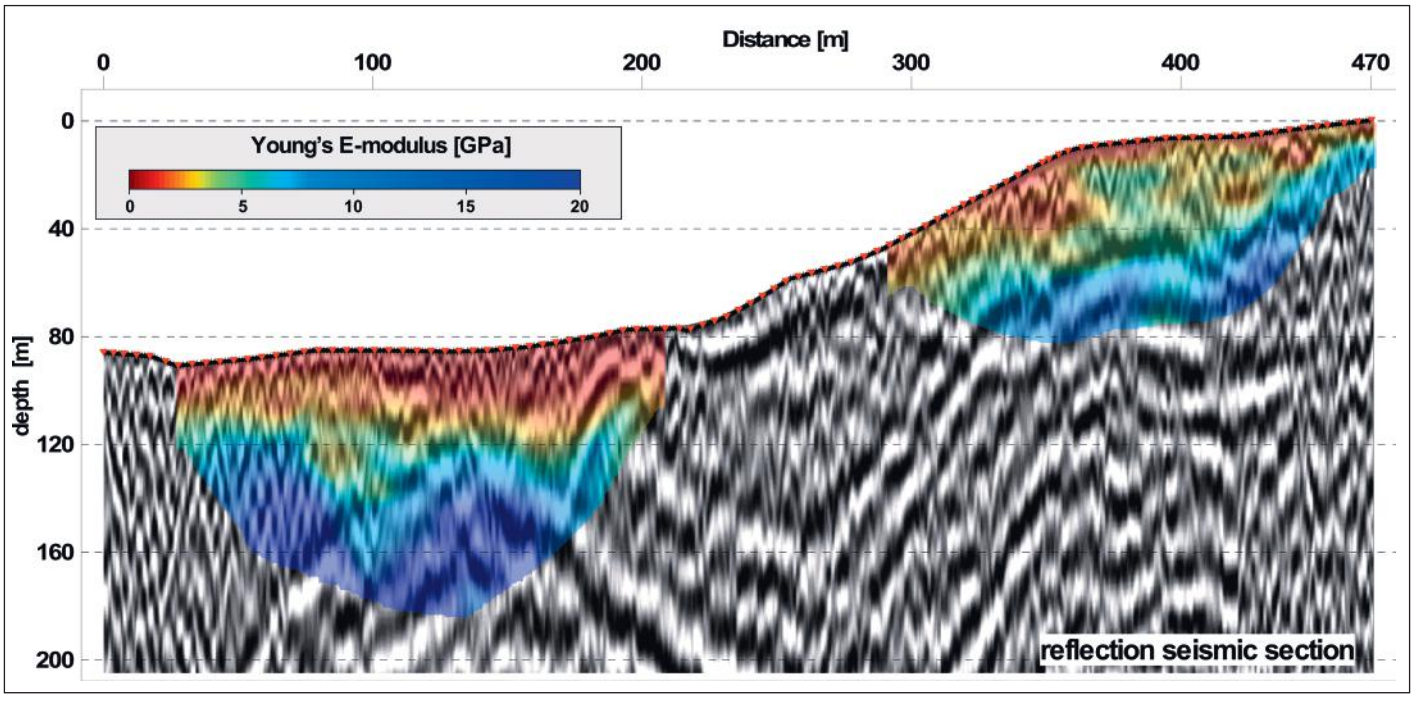

Joint presentation of the ground stability parameter (E-modulus) with geological layering structures and tectonic features