Development of seismic S-wave sources for near-surface applications at the Leibniz Institute for Applied Geophysics (LIAG)

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High-resolution seismic surveys of the near-surface have special requirements for the controlled generation and registration of seismic signals. Compared to conventional P-wave reflection seismic, S-wave seismic imaging has a much higher resolution. In combination, they deliver information on elastic parameters and geotechnical properties of the underground. Due to limited availability, the technical development of specialized seismic sources and other equipment for S-wave and multicomponent near-surface applications is one of the main tasks of the Leibniz Institute for Applied Geophysics (LIAG). Thereby, we investigate new methodical applications for P- and S-waves and we customize the equipment to suite individual requirements, e.g. the application in densely-populated urban areas.

We began the development on S-wave seismics in 2000. Soon, we recognized the advantages of vibrators for S-wave excitation because of a number of reasons, e.g. S-waves are difficult to generate by explosives, other forms of pulse excitation are problematic with regard to reproducibility and signal spectrum, and excessive force can cause ground damage. Coeval with the development of a vehicle-based, hydraulically-driven mini-vibrator (MHV4S) for penetration depths up to 500 m, we also started the work on a much smaller wheelbarrow-based, electro-dynamically driven micro-vibrator for small-scale investigations up to 250 m depth.

The mini-vibrator MHV4S has a large excitation energy and excellent signal reproducibility. Furthermore, it has a high penetration depth and resolution, and allows the use of both P- and S-waves. The vehicle has low sound emission, and is usable in underground buildings and urban areas. Our electro-dynamically driven micro-vibrator (ELViS), patented by LIAG and distributed by Geosym GmbH, has a lower excitation energy than the MHV4S, and it is also non-invasive with an excellent signal reproducibility. Furthermore, it is remote controlled, and allows the use of both P- and S-waves. ELViS is emission-free and due to its low sound level, it is also suitable for night operation in urban areas. It has a high mobility due to low weight, is suitable for air cargo transportation, compatible with all common acquisition systems, and very cost-effective.

At the beginning of our shear-wave investigations, we used plugged geophones, but soon we discovered that Love surface waves and refracted waves, which impair the signal-to-noise-ratio, are suppressed when the survey is carried out on solid ground causing velocity inversion close to the surface. Therefore, we developed a landstreamer, optionally equipped with 1C- or 3C geophones, that enables measurements on sealed surfaces, such as, streets, concrete foundations in industrial buildings, field- and gravel roads, frozen ground, and ice. With the current state of development, we achieve wavelengths below 2 m giving a vertical resolution of 0.5-1 m in the depth range up to approx. 20 m.

In the course of technical and methodological developments over the past 20 years, shear wave reflection seismics at LIAG has opened up a number of new and partly-unique application areas, such as: investigation of contaminated sites of former opencast mines, examination of ice thickness of glaciers, studies of permafrost soils, investigation of quick clay sediments, studies of recent sinkhole processes, examination of soil safety and liquefaction in earthquake areas, and detection of covered, active fault systems for hazard classification.