Extended Abstract

(For Ph.D. Open Seminar)

Development of novel weight-drop seismic energy source for subsurface characterization

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Seismic exploration of the subsurface geological structures has been a fundamental endeavor in the field of geophysics for decades, with applications ranging from natural resource exploration to assessing the seismic hazard of populated regions. Among the various geophysical techniques employed, the analysis of surface waves has gained prominence due to its ability to provide valuable insights into the near-surface properties, which are critical for a wide range of geotechnical and engineering applications.

Surface wave analysis, a subset of seismic exploration, is particularly well-suited for assessing the mechanical properties of the Earth's uppermost layers, including soil and rock profiles. These properties are crucial in understanding and predicting ground motion during seismic events, which is of paramount importance for earthquake engineering and hazard assessment. Furthermore, surface wave analysis plays a pivotal role in geotechnical site characterization for civil infrastructure projects, such as the design of foundations and the assessment of liquefaction potential.

Surface waves are dispersive in nature as its varying wavelengths penetrate to different depths of the layered subsurface. Dispersion of surface waves can be utilized for investigating subsurface velocity structure and thus, for geotechnical site investigation and geohazard analysis.

A man-made energy source is required for seismic imaging of subsurface in which seismic waves generated by the source propagate through various layers in the subsurface and are recorded by the receivers planted on the surface. The acquired seismic signals are further processed and analyzed for different application purposes, for example, detection of faults and fractures, groundwater exploration, geotechnical site characterization, evaluating karst condition, glaciated valley, and others.

Some of the important factors that need to be considered in the selection of a seismic source are: depth of investigation, cost of seismic data acquisition, operational challenges and environmental impacts etc. Commonly used seismic sources for seismic characterization of shallow subsurface include thumper, minivib, airgun, mini sosie, HydraPulse, and VIBSIST, among others. Although some of these seismic sources generate high energy signal, they may not be cost effective and are also difficult to operate and maintain. Furthermore, operational safety of a seismic source needs to be considered, and local government permission may be needed for its use (e.g., dynamite). No thumb rule exists for choosing a portable source for the survey that would provide sufficient frequency range and energy of seismic signal. The specified requirements that can be met may be conditioned by the survey's financial constraints.

The type of source employed for seismic data acquisition has major bearing on the data quality. Signal-to-noise ratio (S/N) and frequency content of the data determines the quality of seismic image and its resolution. When choice of the source is limited due to the budget constraints, a sledgehammer seismic source striking a steel base plate is commonly used. This source has the advantage of being inexpensive, portable, and simple to operate and maintain. The disadvantages, however, are: (i) it produces low-quality seismic signal (i.e., low amplitude vibration and poor S/N ratio), and (ii) its functioning is dependent on the available manpower causing variation in seismic source signature from one shot to another. Furthermore, a hammer source gives low quality dispersion curve at lower frequency range and typically has an investigation depth smaller than 30 m. Other seismic sources which can provide good quality seismic data either require a certificate of permission to operate, or have a difficult operational procedure, or are very expensive. These limitations prompted us to develop a seismic source which would produce a better-quality seismic data for a relatively deeper depth of investigation compared to a hammer source and would be cost effective, portable, repeatable, and easy to operate.

Many researchers have suggested that the efficiency of a seismic source, particularly for surface waves in lower frequency range, can be increased using a heavy weight drop mass. The novel weight-drop seismic energy source is designed and fabricated for Multichannel Analysis of Surface Waves (MASW) studies keeping in mind the cost factor and ease of operation. An attempt has been made to increase the depth of penetration for seismic signal by using a heavy weight drop mass. The current study outlines the design and testing of the novel weight-drop seismic source. In this design essentially a weight-drop accelerated under gravity strikes a base plate that is coupled to the ground. The amplitude and frequency of seismic waves from the impact source depends on several factors including mass and shape of weight-drop and base plate, material of the coupler, falling height, and velocity of impact. The novel seismic energy source is a low-cost equipment constructed from mild steel. It does not require any external power mechanism and has no environmental impact. It can be easily moved in the field and operated by an adult. A test survey is carried out to demonstrate its utility for subsurface imaging using MASW and the quality of seismic data is examined based on the spectral analysis and dispersion curves of the seismic signal. The source's performance, repeatability of source signature, its portability and safety issues are also evaluated.

A brief introduction of the thesis chapters is given below.

Chapter 1: This section comprises an extensive introduction and literature review.

Chapter 2: This section concerns primarily the design, development and testing of novel weight drop seismic energy source.

Chapter 3: This chapter explain about the suitability of developed seismic energy source for MASW survey.

Chapter 4 and Chapter 5 presents the application of developed seismic energy source for seismic hazard studies.

Chapter 6: In this chapter, we bring our thesis work to a conclusion and outline some potential scope and suggestions for future work.