Chapter 9
An Integrated Application Ground Penetrating Radar and Seismic Refraction for Non-Intrusive Investigation of Geophysical and Geotechnical Targets

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ABSTRACT

This chapter presents a brief synopsis of geophysical exploration methods useful in geotechnical and environmental applications. The treatment is keyed at the baccalaureate level to enable geophysics graduates to apply these methods with minimal supervision. In the seismic method, the background theory is given. Application emphasis is placed on the reversed refraction profile technique which ultimately allows interpretation using the Generalized Reciprocal Method (GRM) first introduced by Palmer in 1986. The latter part of the chapter provides a review of the Ground Penetrating Radar (GPR) method used in high resolution geophysical surveys. This method has recently been used extensively to map defects developed on ageing road and pipeline infrastructure in Botswana. The treatment of theory is restricted again to suit the baccalaureate level of geophysics courses at university and many application examples are given. A discussion on acquisition parameters is included to guide the reader through implementation of the method.

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THE SEISMIC REFRACTION METHOD

Introduction

The seismic refraction method is one among a suit of methods available to a geophysicist to investigate the Earth's interior. It makes use of seismic waves that are recorded at the surface after travelling through the Earth along boundaries between layers with different acoustic properties. Seismic refraction investigations can be carried out at three distinct scales: global, crustal and near-surface investigations. The source of waves at global scale is mostly earthquakes and at the other two scales the source can either be explosives and or low energy sources like impact weights. Generally, the waves recorded at the surface represent energy of different wave types that arrive sequentially at the detectors. Together with the direct waves, refracted waves are the first to arrive at the detectors. After recording, refracted waves are processed to determine the velocity of the geologic layers present under the subsurface. For near-surface investigations the seismic velocities obtained can be inverted for geotechnical parameters such as rock strength, rippability, and potential fluid content.

For near-surface work, surveying is done along profile lines which are typically between five to ten times the required depths of investigation (Kearey et al, 2002). Initial interpretation of seismic refraction data assumes planar boundaries between layers. However, refinements can be made later during processing to account for irregularities. The refraction method can be used as a complementary tool to other geophysical methods such as reflection, gravity and magnetic, electrical, and electromagnetic. Its major application is in the oil industry and in regional geological studies (Reynolds, 2011). It can also be used in geotechnical and environmental investigations.

Basic Principles

Snell's law of refraction is at the heart of the seismic refraction method (Telford et. al., 1990; Robinson and Coruh, 1988, Keary et. al., 1990; Sheriff et al., 1990). It relates the *ray parameter* to the angle the ray makes with a line normal to the boundary and the speed of the wave (Figure 1). This parameter is constant along the ray regardless of whether the ray converts into a reflection or other modes. It determines the direction towards which the ray will bend with respect to a line normal the boundary. If a layer the ray enters is of low velocity it bends towards the normal and if the velocity is high it bends away from the normal. A ray that bends away from the normal at an angle of 90° is called a head wave (Stein and Wysession, 2003; Lowrie, 2007) and its corresponding angle of incidence is called a critical angle. At this angle secondary waves are created from the head wave which interfere constructively to build plane wavefronts. The rays emanating from these wavefronts leave the boundary at the critical angle and head up to the surface where they are detected by receivers placed on the ground as refraction arrivals.

Before the critical angle is reached, most of the wave energy is transmitted. After the critical angle, most of the wave energy is returned back to the surface. This situation is referred to as total internal reflection.

Limitations of the Refraction Method

Among other things that can ensure the correct implementation of the seismic refraction method: