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Geotechnical studies for evaluation and limitations of environmental and engineering hazards that affect the economic infrastructure in Abha, Saudi Arabia

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Abstract Abha is the capital of Asir province in Saudi Arabia. It is situated 2200 meters (7200 ft) above the sea level in the fertile mountains of the south-western Saudi Arabia. One of the most important structures of this region is Abha dam that acts as a barrier that impounds water or underground streams thereby retaining the ground water of the region. With the passage of time, various environmental factors such as ground movement, wind and changes in temperature may have significant effect on these various structure factors and may lead to invisible cracks and other structural defects. Because the dams and tunnels are prone to sudden collapse, there is potential great risk to lives of the people and significant economic loss in this area. The use of the ground penetrating radar (GPR) and electric resistivity techniques is a non-invasive scan and could assess the conditions of various built structures as well as the earth beneath or surrounding it. So the GPR system with appropriate types of antennas (1.5 GH, 1 GH, 400 MH and 100 MH) and electrical resistivity in one dimension (VES) and two dimensions (electrical profiling and imaging) is used in this work. This work aims to investigate the dam structure, developing cracks or areas of increased moisture. Also to study the surrounding areas to detect seepage from pond that may affect nearby buildings and the dam itself.

It reveals that, the depth of water bearing layer ranges from 2 m to 10 m, where the three geoelectric layers are present. The first layer has resistivity values ranging from 44 Ω m–1200 Ω m with thickness ranging from 3 m to 18 m that is interpreted as the wadi deposits. The second layer having resistivity values from 11 Ω m to 137 Ω m is interpreted as the water saturated in the fractured basements. The

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third layer of resistivity values ranging from 2200 Ω m to 90,000 Ω m is interpreted as dry, massive basements. The GPR results provided internal images of the slab, showing its morphology, areas of possible damage and changes to the structure, and the situation of the steel reinforcements. It showed the presence of different shapes of fractures and voids with the growing of moisture zones.

1. Introduction

Increased public awareness of pollution in the environment in both the industrial and military sectors as well as geotechnical and engineering problems have encouraged a continuing search for innovative and cost-effective means for understanding near-surface structure. More and more contractors and government agencies over the past few years have recognized the benefits and cost savings of using geophysical methods in conducting their geotechnical investigations. Newer and more capable instruments combined with faster computers have enabled the widespread use of various methods for locating and identifying subsurface features and structures that will impact construction designs.

Applied geophysics investigates the physical properties of the ground, providing vital information on subsurface material conditions for numerous practical applications. Geophysical investigations are non-invasive and avoid the disruption caused by invasive testing such as drilling and pitting. In environments where invasive investigations are not permissible, geophysics can provide detailed information on subsurface structures and help answer questions for successful construction and infrastructure maintenance of large areas. The Physics Department of King Khaled University provides geophysical services for civil engineering, environmental science, archeology and non-destructive testing applications.

Abha is the capital of Asir province in Saudi Arabia. It is situated 2200 meters (7200 ft) above sea level in the fertile mountains of the south-western Saudi Arabia. One of the most important structures in this region is Abha dam (Fig. 1), that acts as a barrier that impounds water or underground streams there by retaining the ground water of the region.

With time, various environmental factors such as ground movement, wind and changes in temperature may have significant effect on these various structure factors. These factors may lead to cracks and other structural defects may be invisible. Because the dams, tunnels are prone to sudden collapse, there is potential great risk for the people and economy (Tsoflias et al., 2004).

One of these cost-effective methods for non-invasive sub surface scanning is the ground penetrating radar (GPR) technique. This technique is used successfully in the detection of cracks, voids and other anomalies appearing with the aging of such materials. GPR is a pulse echo method for measuring pavement layer thickness' and properties. GPR uses electromagnetic waves to penetrate the pavement by transmitting the wave energy into the pavement from a moving antenna. These waves travel through the pavement structure and echoes are created at boundaries of dissimilar materials. The arrival and strength of these echoes can then be used to calculate pavement layer thickness and other properties like moisture content. It is therefore necessary to do a geotechnical survey to determine the extent of the stability of these components of the infrastructure (Davis and Annan, 1989; Davis et al., 1984).

An evaluation of the physical condition of concrete is crucial for predicting the life of reinforced concrete structures. For example, it is well known that water and chloride contents are among the concrete features that govern reinforcing bar corrosion (Andrade et al., 1999; Raupach, 1996). It is then necessary to assess the spatial distribution of these physical features throughout the structure to improve the pathology diagnosis. However, the on-site evaluation of these durability indicators is difficult and often requires destructive tests (Matthews et al., 1998).

Among the various non-destructive evaluation techniques, radar has become an interesting instrument for the rapid evaluation of reinforced concrete structures regarding the detection and location of buried objects such as steel rebar. In addition, radar waves propagating through concrete are affected by changes in the moisture content. For example, several authors have reported that radar wave velocity is reduced when the concrete moisture increases (Laurens, 2001; Klysz et al., 2004; Sbartaï, 2005). Recently, Sbartaï et al. (2006a) showed that an increase in the chloride content of concrete leads to a significant decrease in the amplitude of both direct and reflected waves. In addition Sbartaï (2005) also showed that the velocity of radar waves is mainly affected by moisture variations. For dry and wet concrete, water/concrete ratio did not appear as an influent parameter on radar signals variation (Sbartaï et al., 2006b).

Results are presented in an easy way to understand engineering compatible CAD format. A typical ground radar system comprises an antenna unit, control console, display monitor and graphic printer. The antenna unit is in direct ground contact, with the remaining equipment either vehicle-mounted or stationary. Data are collected along accurately located profiles, usually set-out in a survey grid.

Variable frequency, interchangeable antenna units can be used with the GPR system, depending on the particular application. Low frequency units offer greater depth penetration and are generally better suited for civil engineering and geological site investigations. Small, portable, high frequency units are used for high resolution work involving of concrete and masonry structures.

2. Methodology

2.1. Electric resistivity technique

The main aim of a resistivity survey is the measurement of the electrical resistivity of the earth, knowledge of which enables the estimation of its hydrogeological properties. The first step toward this is the measurement of the resistance of the ground