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Detection and Location of Subsurface Voids Using Seismic Resonance Waves

Roland Gritto (1), Valeri Korneev (1), Elnaiem Elobaid (2), Fathelrahman Mohamed (2), and Fadhil Sadooni (2)
(1) Array Information Technology, Berkeley, United States, (2) Qatar University, Doha, Qatar

A major hazard in Qatar is the presence of karst, which is ubiquitous throughout the country including depressions, sinkholes, and caves. Causes for the development of karst include faulting and fracturing where fluids find pathways through limestone and dissolve the host rock to form caverns. Of particular concern, in rapidly growing metropolitan areas that expand in heretofore unexplored regions, are the collapse of such caverns. Because Qatar has seen a recent boom in construction, including the planning and development of complete new sub-sections of metropolitan areas, the development areas need to be investigated for the presence of karst to determine their suitability for the planned project. In this paper, we present the results of a study to demonstrate the use of seismic spectral analysis techniques to detect and locate the presence of a karst analog in form of a vertical water-collection shaft located on the campus of Qatar University, Doha, Qatar. We also present the results of this technique to characterize the overburden over a sinkhole in the Al Duhail Area of Doha, Qatar.

In our current paper we employ spectral techniques to demonstrate the detection and characterization of a vertical water collection shaft analyzing ambient seismic noise recordings that have been scattered by the object. The results indicate that ambient noise recordings may generate data with sufficient signal-to-noise ratio to successfully detect and locate subsurface voids. In our study on the campus of Qatar University, we deployed 48 10 Hz three-components geophones and passively recoded ambient seismic noise data. The 24 m long geophone line ran across the top of the water-collated shaft and extended to both sides. Spectral analysis of the ambient noise data revealed an increase in low frequencies directly above the vertical shaft. The low frequencies are attributed to resonance waves that propagate circumferentially in the concrete walls of the vertical shaft. The observation of increased low-frequency energy was accompanied by a decrease in high frequencies clearly demarking the location of the shaft. In contrast to the increase in amplitude of the low frequency resonance waves, the high frequencies of ambient noise were attenuated by the presence of the shaft. The clear demarcation of the increase and decrease in amplitudes of recorded waves by the geophones located above the shaft allows to pinpoint its location. In the second part of our paper, we analyze scattered seismic waves obtained during an active seismic survey to characterize the overburden of a sinkhole in the Al Duhail Area of Doha. Using a similar approach, spectral analysis of active source seismic data revealed the extent of the sinkhole, while analytical modeling of the recorded data reveals the thickness of the overburden.