Application of GPR to Identify Carbonate Rock Cavities Related to Ground Subsidence in Matale, Sri Lanka

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Abstract
Cavity formation within the rocks result in ground subsidence in the regions where carbonate rocks are predominantly present. Identification of ground subsidence potential areas and the probability of such incidents is a challenge without detailed information about the subsurface. Dorakumbura in Matale, Sri Lanka is one such area which faced multiple ground subsidence incidents that demands the investigation of subsurface profile. This study uses Ground Penetrating Radar (GPR) to locate the subsurface cavities in order to create a cavity profile for the Dorakumbura area using 1D and 2D trace analysis of the radargrams. Cavities were identified and analyzed and the results reveal the existence of cavities mostly below the depth of 15 m. Comparison of GPR survey results with the well log data in the region was equivalent. The same methodology is expected to be used in similar regions to identify the presence of cavities which can result in future ground subsidence. It can also assist in suitable site selection without ground subsidence hazards, for the construction and development activities in regions underlying carbonate rocks in Sri Lanka.

Keywords: Ground subsidence, Radar surveying, Rock cavities, Subsurface exploration

1. Introduction

Ground subsidence occur due to the settlement of low density soil and voids created naturally or anthropogenic actions. Although subsidence doesn't occur abruptly in nature, such occurrence can result in dangerous impact in human as well as physical structures [1].

In Sri Lanka, Matale area is prone to ground subsidence, mainly due to the presence of cavities in the carbonate bedrock. Considerable number of ground subsidence incidents were recorded in areas of Dorakumbura, Thotagamuwa, Dunkolawatta, Nagolla, Ukuwela and Palapathwala in the Matale District.

To determine the presence and extent of the cavities that are responsible for ground subsidence , demands comprehensive approach of subsurface investigations. These can be conducted with invasive and/or noninvasive techniques [2]. Constructing a drill hole (borehole),

trench or a pit is an examples for most common invasive techniques in geotechnical investigations to obtain subsurface information. [3].
Electrical resistivity, magnetic, seismic, gravity and ground penetrating radar surveys are some of the commonly used non-invasive techniques. They have the ability of rapid exploration of larger areas with limited disturbances to the environment. The indirect methods measure at or near earth properties which are usually influenced by the internal physical properties of the subsurface. The main advantages of using indirect exploration techniques over direct methods are; cost effectiveness and high efficiency [4].

1.1 The Study Area

Dorakumbura area off Thotagamuwa Junction is located on A9 road between Matale and Dambulla, which is also in the Matale District of Central Province in Sri Lanka. A considerable proportion of the Matale district is comprised with carbonate rock terrains.

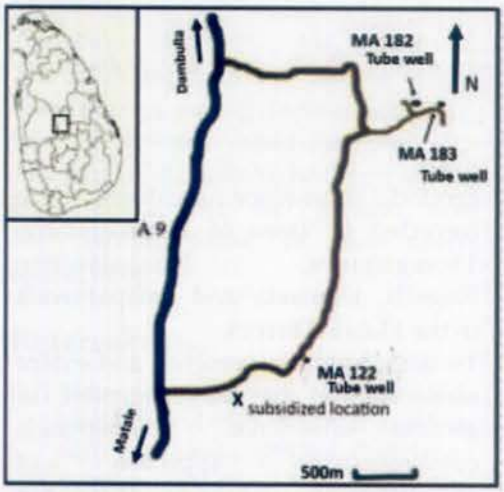

Figure 1 - Survey locations in Dorakumbura, Matale

Geographically, the study area lies almost at the centre of Sri Lanka and has an undulating topography. Geologically Dolamitic Marble is the prominent rock type in the area, which are interlayered or mobilized into surrounding rocks like garnet-sillimanite gneiss, charnockitic gneiss and quartzite.[5].

Four study locations in Dorakumbura, were selected to conduct the GPR survey. Those included three existing tubewell locations with well-log data available and one location which has experienced ground subsidence recently [Figure 1].

2. Methodology

From the available geophysical methods, ground penetrating radar was selected to conduct the survey for cavity investigations, due to rapid exploration capability in a larger extent with sufficient reliability, less time consumption and easy handling.

2.1 Preliminary Investigations

Information on the study area were gathered through the literature survey. Further details were obtained using available topographical and geological maps in the area. Preliminiray site visit was conducted to locate surveying locations with respect to the location of ground subsidence and tubewells for which the well log information was available.

2.2 GPR Surveying

GPR surveying was conducted at four locations in several traverses surrounding the locations of interest (Figure 2). The orientations of the survey lines were strictly maintained with fixed starting and end points and GPR data were gathered. The radargrams were processed with the "GPRSoft PRO" software with the application of appropriate parameters for the desired conditions.

2.3 Validation with Well-logs

Drill-hole data obtained during the tubewell construction of Dorakumbura area indicate the presence of cavities at those locations[6].

Hence, the processed radargrams generated from the GPR surveying, surrounding the tubewell locations were compared with borehole cross sections of the well logs to validate the GPR interpretations and confirm the possible vertical extent of the subsurface cavities. Figure 2 to 5 represent the survey lines used in Dorakumbura area, and all the dimensions in thses figures are in meters.

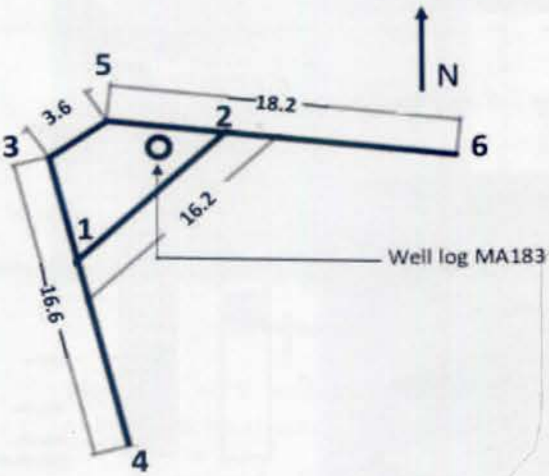

Figure 2 - GPR survey lines at location MA 183

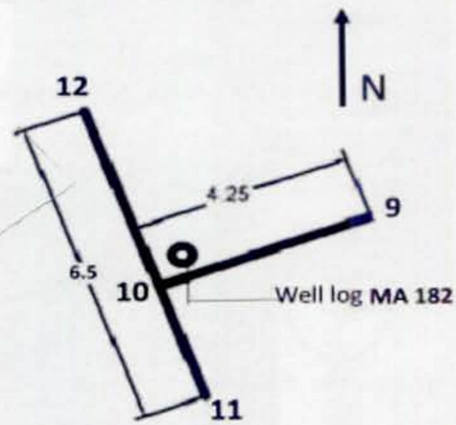

Figure 3 - GPR surveying lines at location MA 182

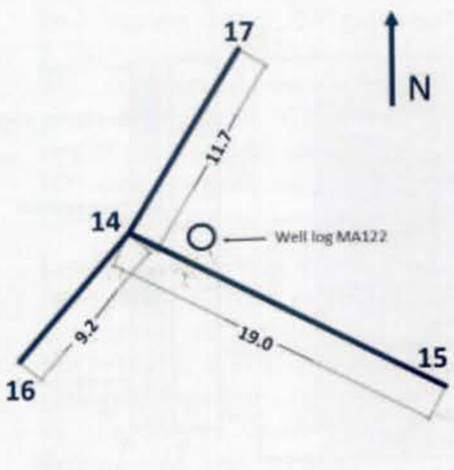

Figure 4 - GPR surveying lines at location MA 122

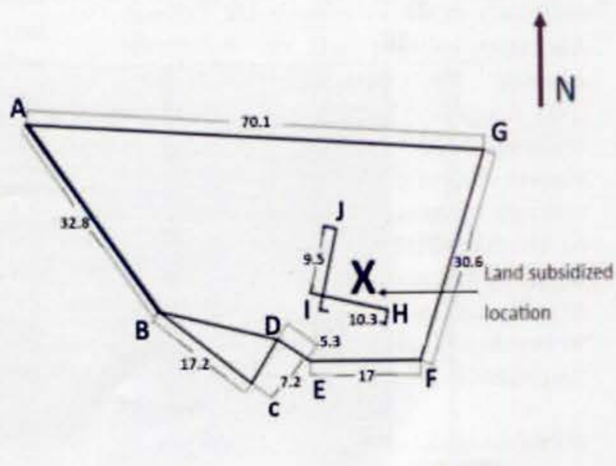

Figure 5 – GPR Surveying lines and ground subsidized location X

3. Results and Discussion

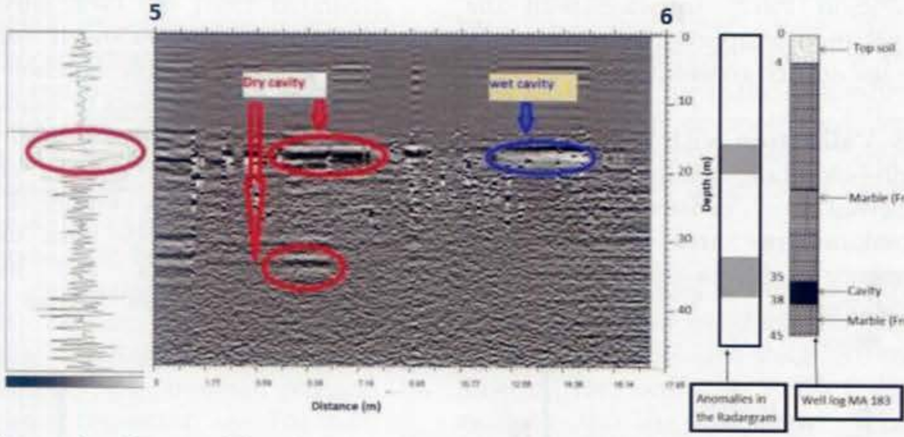

Figure 6 - GPR profile of survey line 5-6 and well-log at location MA183

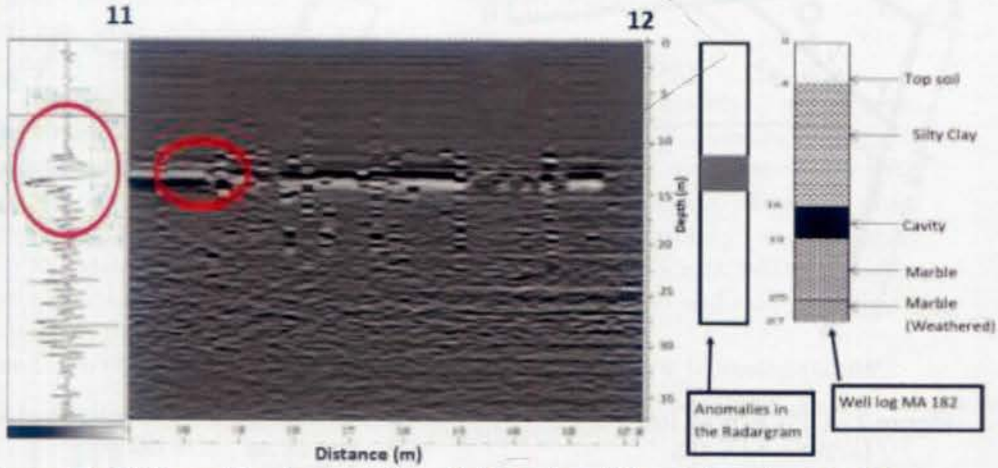

Figure 7 - GPR profile of survey line 11-12 and well-log at location MA182

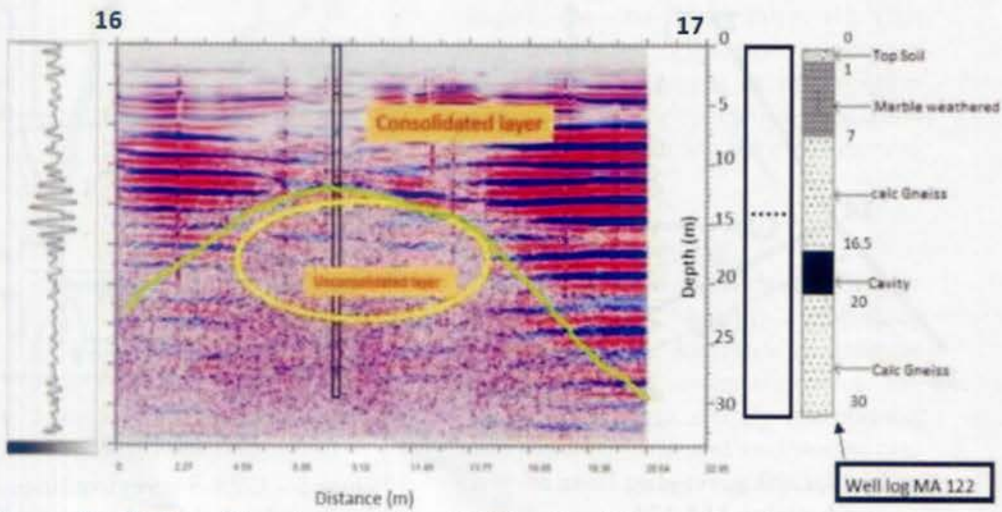

Figure 8 - GPR profile of survey line 16-17 and well-log at location MA 122

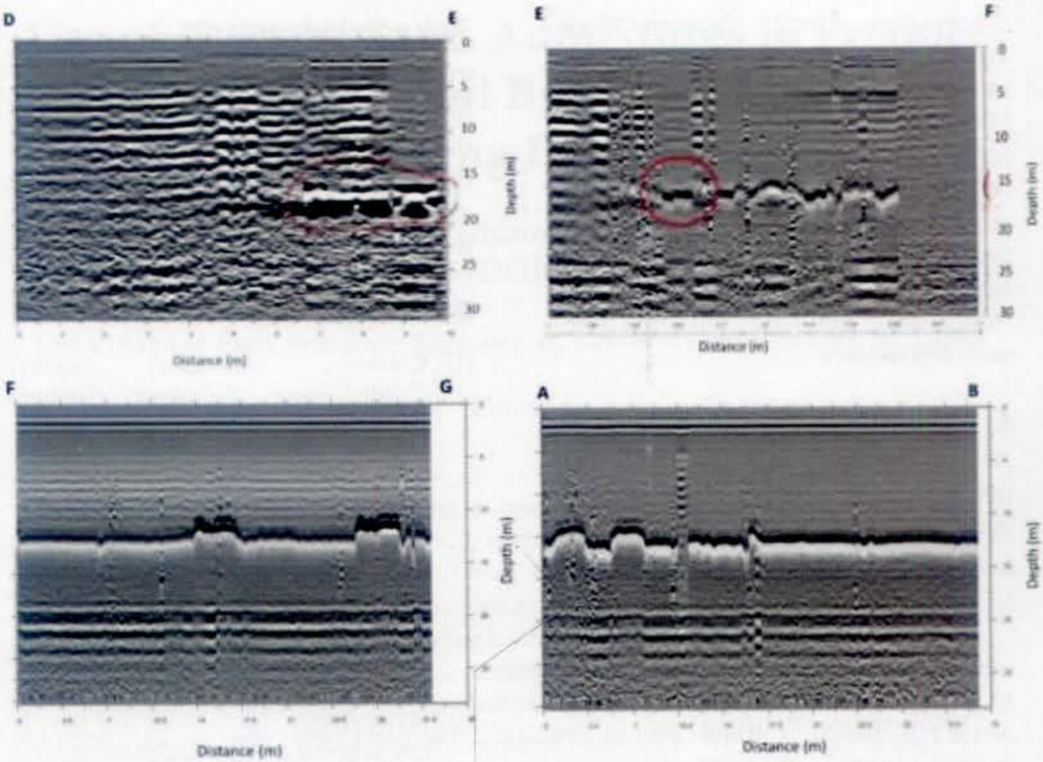

Figure 9 - GPR profiles of the survey lines DE, EF, FG and AB at recently subsidized location -X

Acquired GPR data were processed and interpretations were made to identify possible cavities on the radargrams. GPR profiles and corresponding cross-sections of tube well-logs are shown in Figures 6, 7 and 8. Survey results from the location that has experienced the subsidence is given in Figure 9. When 2D analysis could not provide clear information, 1D (trace) analysis was used to identify the anomalies [7].

Presence of cavities at the depths of 15 m can be directly recognized on the radargrams at locations MA182 and MA183. This is in accordance with the tube-well logs but with a slight offset in the depth observed from the drilling. At the location MA122 a cavity cannot be directly identified, however the presence of an unconsolidated soil layer below 10-15 m is visible.

Similar observations on cavities around the depths of 15 m could be identified on the profiles obtained from the location of ground subsidence occurred (Figure 9). Accordingly, the GPR profiles generated on the entire region reveals anomalies indicating possible cavities approximately beyond the depths of 15 m. The vertical thickness of these cavities indicate approximately 5 m in every location. However, the extent of the cavities could not be determined from the available data.

Presence of the unconsolidated strata around the same depth was influential on the clarity of the radargram observations and interpretations. Weather conditions had minimal influence on the surveying results, However, the interferences from the soil moisture content cannot be completely neglected. Considering the environmental evidence and the available geology data, presence of the salts were unlikely and quality of results may not have hindered with such distractions.

4. Conclusions

As per the findings of this research, the following conclusions can be made:

- The GPR results are comparable with the previous borehole logs obtained during the tube-well constructions. The results reveal the existence of cavities mostly below the depth of 15 m.
- Using GPR analysis results, it is possible to make preliminary predictions on the type of cavity filling material as air, water or soil.

5. Recommendations

GPR survey can be recommended to identify the presence of cavities which results in future ground subsidence and for the selection of suitable sites without any ground subsidence hazards, for the construction and development activities in regions underlying with carbonate rocks.

To estimate the size and distribution of a cavity, conducting of the survey in a pre-defined grid is recommended.

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