A CASE STUDY OF GROUND PENETRATING RADAR FOR NON-DESTRUCTIVE TESTING APPLIED TO UNDERGROUND GEOLOGICAL STRUCTURES

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ABSTRACT

The applicable fields of NDT (Non-Destructive Testing) are extensive nowadays and among these fields, underground geological structures provide significant value for study and engineering application. In particular, it is crucial to understand the geological status (e.g. underground water level, cavities, tilting, weathering, etc) of an area prior to many developments. Otherwise, additional losses will be generated during development. More seriously, the geology of specific area might be influenced and damaged. This case research used the case of ground penetrating radar under NDT for on site culvert to discuss the significance of GPR (Ground Penetrating Radar) in regard to the underground geological structure, the cavity. After experimentation, it was verified that GPR was capable of testing underground geological structures. The cavity was approximately 1 cubic meter in size and 0.9 m deep from ground surface. With such result, it can be observed that ground penetrating radar is a useful tool for testing, and can provide reference for future researches and engineering applications.

Key Words: GPR (Ground Penetrating Radar), Cavity

INTRODUCTION

The The collision between the Eurasian Continent and Philippine plate (as shown in Figure 1) caused the complex underground geological structure of Taiwan and such structure is a great challenge in the study of geotechnical engineering. At present, studies in this field include: seismic testing, drilling, geo-electricity, etc. However, it is often difficult to decide whether or not to commence the studies since the landscape and object often cause problems in regard to site damage and huge funds required. If a technology with non-destructive, fast and high resolution features can be used to survey the status of underground geological structures, various technical bottlenecks experienced in the past can surely be solved.

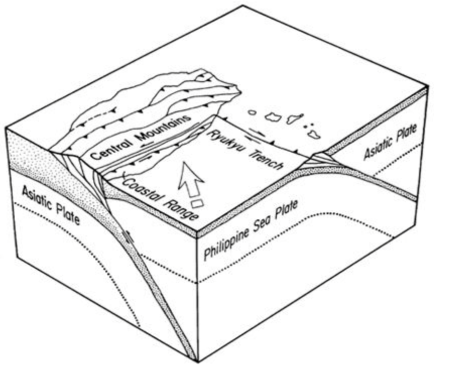

Fig. 1: The structure of Taiwan Island

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The GPR applies the principle of detecting a target object with radar wave reflection that generates 16MHz to 2Gz of radar wave for the duration of a nano-second (ns) via a power discharge coil of several hundred volts. The wave penetrates underground or building structures and then such incident wave is reflected to the ground surface via the underground stratum interface of different electromagnetism, where highly sensitive antenna will receive partial signals and automatically store them. The recording time is determined according to detecting target for a minimum of 1 ns and maximum of 32,767 ns. After general processes, such as compensation for declined amplitude and filter plus special processes including speed analysis, de-convolution and displacement, the data recorded generates a double wave section and this is used to plot the profile of the underground stratum and detect artificial objects buried underground.

Figure 2 is an illustration of a GPR survey. When moving along the ground, the GPR transmits a wave to penetrate the stratum and reach the interface below ground surface. The reflected wave generated is picked up by reception antenna when it returns to the ground surface.

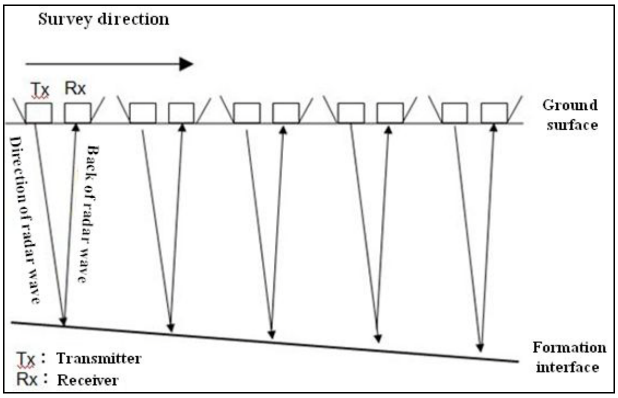


Fig. 2: Illustration of GPR survey

The SIR-3000 machine (Figure 3) and 400MHz antenna (Figure 4) were used as the GPR equipment in the case.

Fig. 3: GSSI SIR-3000 machine

Fig. 4: 400MHz antenna

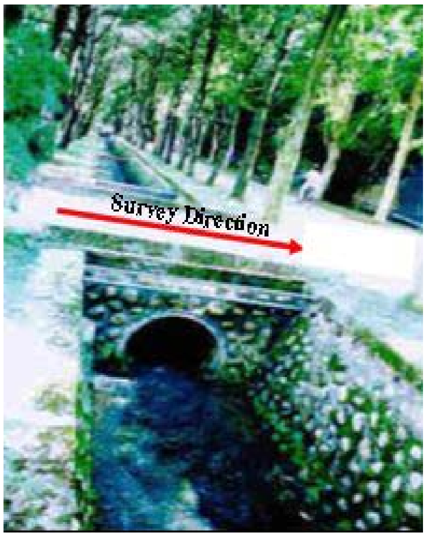
Literature Review

The application of NDT in the engineering industry is very extensive. Taking the cavity test in underground structure for example, many experts and scholars have produced discussions and studies. Davis and Annan (1989) [1] explored the underground stratum structure or fault. In the studies made by Kovas (1991) [2] and Mellet (1992) [3], the results indicated positive opinions on determining the location of unknown objects underground with GPR. Zolotarev *et al.* (1996) [4] made the cavity survey. When Tung and Huang (1994) [5] used GPR to survey the structure of shallow stratum, the results of interpretation were very easily affected by noise. After filter processing of the horizontal noises, the stratum status was able to be expressed more clearly. Lee *et al.* (1999) [6] applied GPR to survey the parallel piping and underground holes, and concluded that the position and size of holes could be determined according to the crest of the double curve and abnormally smooth section near the crest from radar's sectional image. Tung *et al.* (2002) [7] applied the geotechnical engineering NDT to survey underground structure and environment. Li *et al.* (2003) [8] used a practical case to discuss the application of GPR data interpretation for detecting an underground cavity, where the study results could be used as reference for future studies on liquefaction and the hollowing of underground stratum. Chen (2003) [9] adopted GPR for the simulation of cavity detecting, where the size of the cavity inside the hydraulic embankment could be evaluated rapidly from the interpretation results. Wu and Chang (2007) [10] used GPR to test the underground status of roads and confirmed whether or not, the stratum under the road was hollowed, thereby providing a basis for evaluating road safety. From the above literatures, it is known that the use of GPR to survey the status of underground structure has become a popular procedure.

Data Collection

In this study, the gutter cavity on the campus of National Central University (Picture 1) was used for an experiment on surveying an underground cavity with GPR, So that the interpretation and verification could proceed.

Picture 1. Current status of underground cavity



Picture 2. Illustration of GPR Detect on site

Analysis and Interpretation

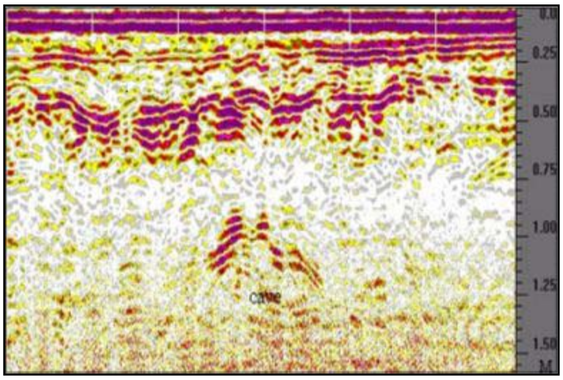


Fig. 5: Original section of GPR

(1) Based on the original section (Figure 5) obtained from GPR detect (Picture 2), the position and depth of the cavity could be observed, which indicated that GPR was a fast detecting instrument with high resolution.

(2) After processing the original section with filter, the position and depth of the cavity could be seen even more clearly (Figure 6).

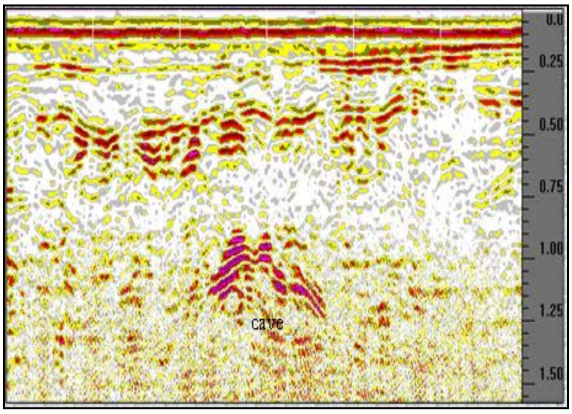


Fig. 6: Section after filter process

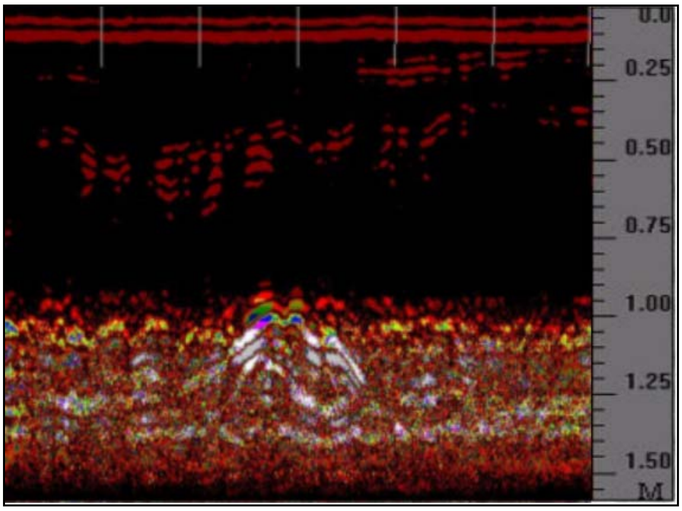


Fig. 7: Gain process

(3) After processing the filtered section with gain, the position, size and depth of the cavity were highlighted (Figure 7).

(4) By processing with different colors, the cavity could be interpreted with another section (Figure 8).

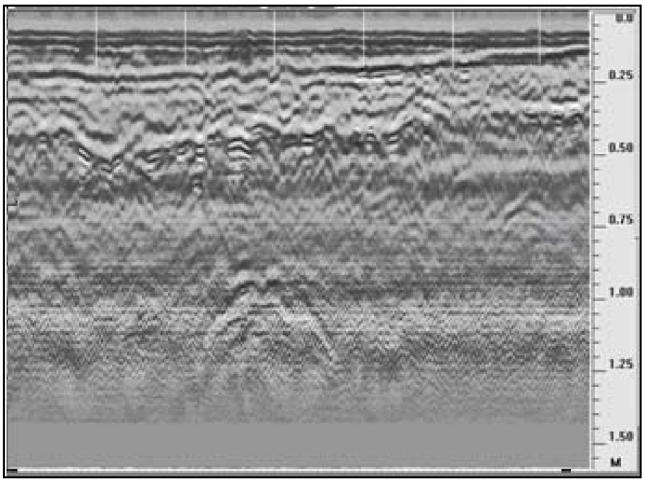


Fig. 8: Section processed with different color

From Figures 6, 7 and 8 of the processing section derived from testing with filter, gain and color, the position, size and depth of the cavity could be identified more clearly.
After interpretation on the section, the correct position of the cavity was approximately 0.9m deep, with the size of 1cubic meter, which could be used as reference for future studies with GPR.

CONCLUSIONS

(1) The correct position of the culvert was approximately 0.9m deep with a size of 1cubic meter.
(2) The non-destructive GPR can be used as reference for future studies of underground structures.

The case research results can be used as reference for future researches related to the testing of geotechnical structure and GPR applications, which are expected to provide more data for further analysis with an integrated database.

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