Field test on application of detecting materials for maintenance of the restored cavity

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ABSTRACT: In this study, the field test on GPR detection was performed by the various detecting material in order to evaluate the applicability of the detecting material for GPR detection in maintenance of the restored cavity. The results showed that the applied material was detectable by GPR regardless of type, size and the buried depth of the detecting material. Therefore, it confirmed that the application of the detecting material was possible according to the restored method of cavity because the all detecting materials can be utilized for the application the GPR detection

Keywords: GPR, Detecting material, Electromagnetic interference (EMI), Ferronickel slag

1 INTRODUCTION

Recently, GPR (Ground Penetrating Radar) detection with high reliability has been utilized to survey the cavity in underground. GPR detection, which has the reflection and diffraction characteristics of electromagnetic waves, is a geophysical exploration method in relatively shallow depth (Lee & Son, 2016). As mentioned above, GPR detection, which is a kind of nondestructive inspection, is possible to investigate the shallow ground and the buried pipe. GPR detection is very efficient, because the underground cavity of the urban occurs mainly at depths close to the ground surface, in Korea. That is, the Restoration and maintenance of cavity are needed based on the results of the cavity detection.

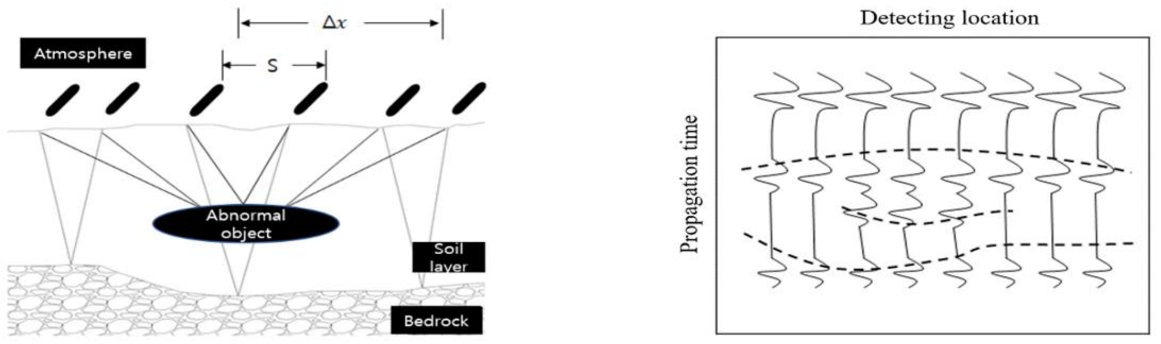
In this study, the field test on GPR detection was performed by the various detecting material in order to evaluate the applicability of the detecting material for GPR detection in maintenance of the restored cavity.

2 PRINCIPLES OF GPR DETECTION

A wave like a sound wave is classified as a longitudinal wave and transverse wave. The longitudinal wave has a characteristic that the direction of wave progress coincides with the direction of particle vibration, and the transverse waves has a perpendicular to the direction of the wave vibration. This concept is mainly used in seismic exploration, and it applies to most wave movement (Lee, 2005).

Electromagnetic waves are included in transverse waves by the classification of waves, because the vibration direction of the electric force line and the magnetic force line in the electromagnetic waves is perpendicular to the direction of wave progress by Snell's law (Choi, 2006). That is, the electromagnetic

waves are linear in the same medium, and it has a property of reflection and refraction at the interface of material when other materials are constituted.
Radar system has several methods such as reflection, CMP velocity sounding, and radar tomography. The most commonly used surface radar detection is called GPR detection. GPR detection is similar to seismic reflection method and uses high-frequency electromagnetic energy with short-pulse (Wi, 1999). The transmitted electromagnetic energy in underground changes according to the permittivity and electrical conductivity of the material. Fig. 1 (a) (Davis and Annan (1989)) shows the concept of radar detection. The electrical properties of material can determine the velocity, attenuation, and voltage of the reflected radar signal at the interface as shown in Fig. 1(b).



(a) Concepts and models of radar detection (b) Results of radar detection
Figure 1. Radar detection concept and record results

3 FIELD TEST METHOD AND CONTENTS

3.1 *Engineering properties of soil in field*

In general, soil is classified as unified soil classification system (U.S.C.S.) according to characteristics of soil such as particle size, Atterberg limit, specific gravity, and specific gravity. In addition, the permittivity of soil affect GPR detection is different depending on soil type, water content, and compaction characteristics. In the previous study (Park, 1998), that the permittivity of the classified soil as SW, SP, and SM has been evaluated as 11.9, 11.1, and 8.6, under the water content and the relative compaction were about 12 and 88% ~ 95%, respectively.
Table 1 shows the engineering properties of soil at field. The result analyzed that the soil in field was a sand mixed with silt (SM) by U.S.C.S..

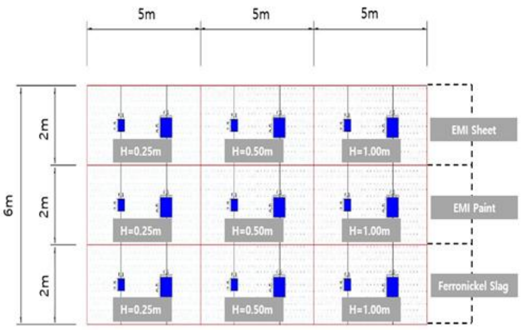
Table 1. Engineering properties of soil

Classification	Natural water content	specific gravity	Particle size distribution	Atterberg limit (%)		Compaction test		U.S.C.S.
			# 200	LL	PI	w_{opt} (%)	$\gamma_{d(max)}$ (kN/m^3)	
Site sample	12.4%	2.68	42%	25.5	4.2	11	19.3	SM

3.2 *Field test*

Figure 2 shows the process of the GPR detection in field. Each detecting material (EMI Sheet, EMI paint, Ferronickel slag) was made in square of 0.25m and 0.5m, and then it was buried at 0.25m, 0.5m and 1.0m depth from the ground surface (see Fig. 2(a)). In addition, the buried detecting materials was considered to be the interval without the interference effect of detecting materials at the GPR detection.
The procedure of field test is summarized as followed;
(1) VRS survey was carried out for each buried position after expression the buried position of detecting material. (Fig.2(b)).
(2) Detecting material was installed at each buried location after excavation of the buried depth. (Fig.2(c) ~ Fig.2(f))

(3) GRP detection was performed at each location using the measured coordinates after the soil cover. (Fig.2(g))

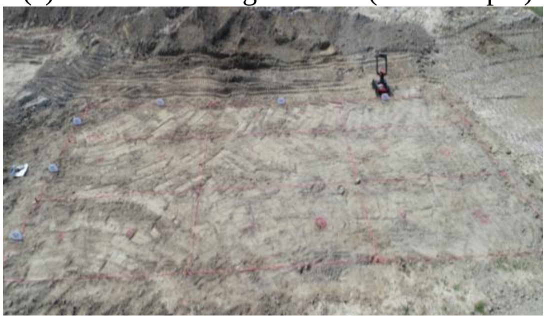


(a) Overview of GPR Detection

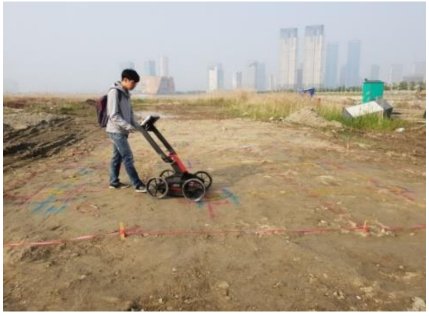
(b) Ground excavation

(c) Buried detecting material (0.25m depth)

(d) Buried detecting material (1.0m depth)



(e) Soil cover completion



(f) View of GPR detection

Figure 2. GPR detection progress

3.3 *Properties of detecting material*

Detecting materials used in this study are electromagnetic shielding materials and ferronickel slag. The electromagnetic shielding material, which has excellent in vapor permeability, tensile strength and electromagnetic wave shielding rate, was applied in paper and liquid form. The ferronickel slag, which is composed of nickel (20%) and iron (80%), is applied as the main ingredient of stainless steel. Kim (2018) analyzed that the detection ratio of abnormal signal is increase when the iron content in the slag increase. Fig. 3 shows the kinds of the applied detection materials in field test.

(a) EMI Sheet

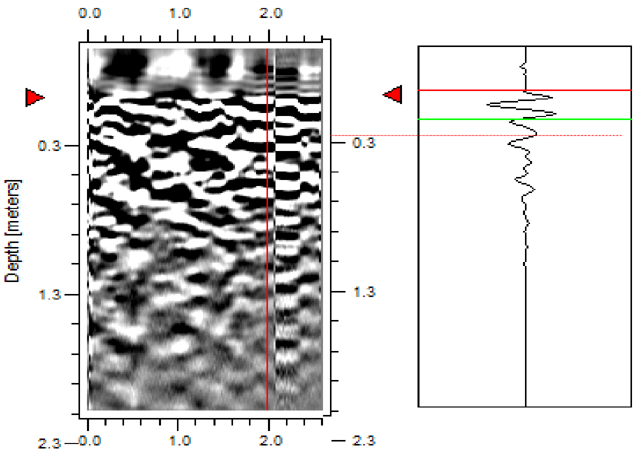
(b) EMI Paint

(c) Ferronickel slag

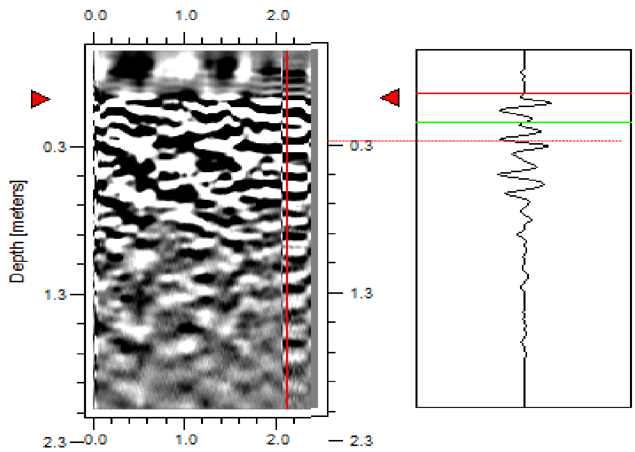
Figure 3. Detecting materials

4 GPR DETECTION RESULTS

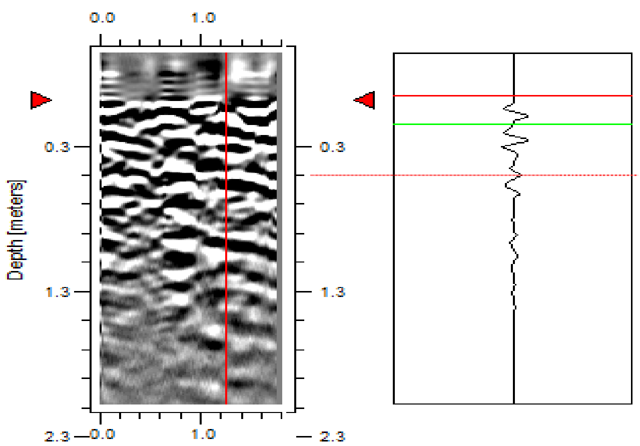
Fig.4 ~ Fig. 6 show the result of GPR detection according to the buried condition of the detecting material. The contour of detection results with detecting material was reversed compared to the soil without the detecting material at the same depth. This means that electromagnetic waves are disturbed because of other materials (detecting material) in the ground. The relative permittivity was confirmed to ensure the reliability of the detection results. The results showed that the direction of permittivity value with detecting material was opposite to that of permittivity value without detecting material. The same results were obtained at all buried depth conditions. That is, it confirmed that the applied material was detectable by GPR regardless of type, size and the buried depth of the detecting material. Therefore, the detecting material can be reasonably applied according to the restored method in order to be a maintenance of the restored cavity, because the depth of cavity in urban areas occurs mainly within 1.0m.



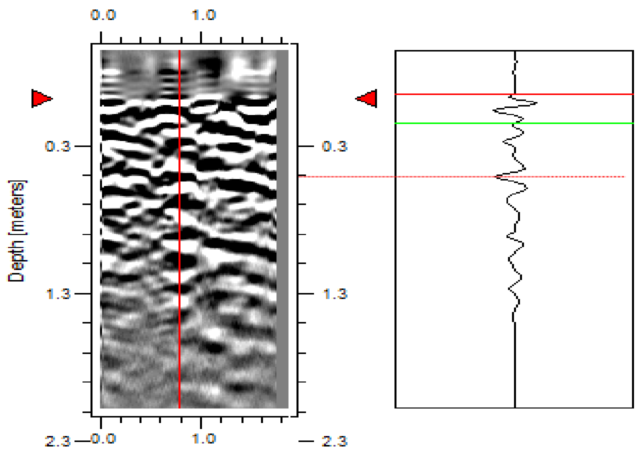
(a) Section without the detecting material (0.25m)



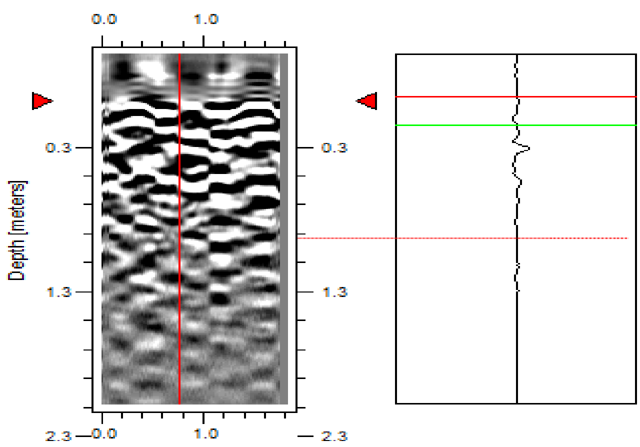
(b) Section with the detecting material (0.25m)



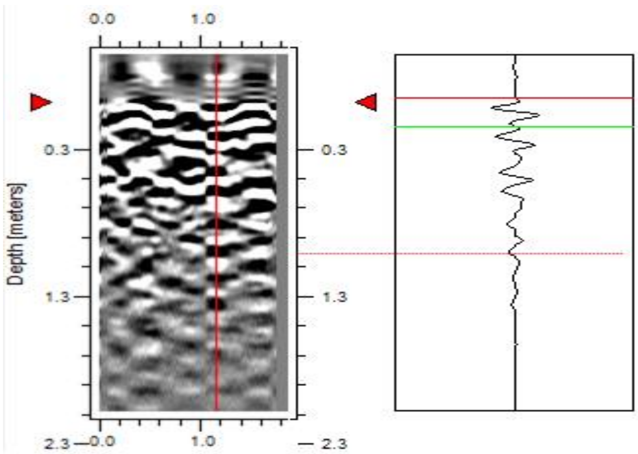
(c) Section without the detecting material (0.5m)



(d) Section with the detecting material (0.5m)

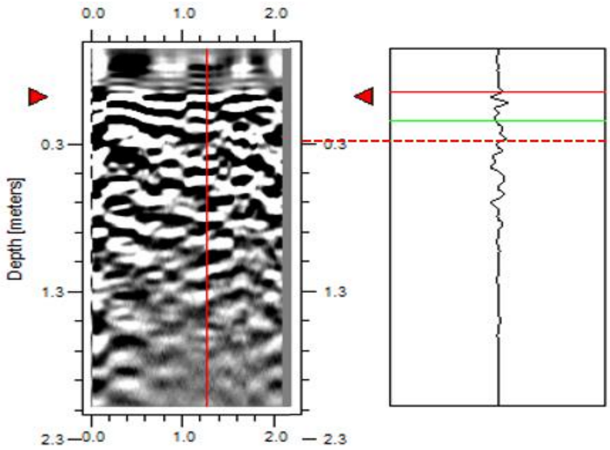


(e) Section without the detecting material (1.0m)

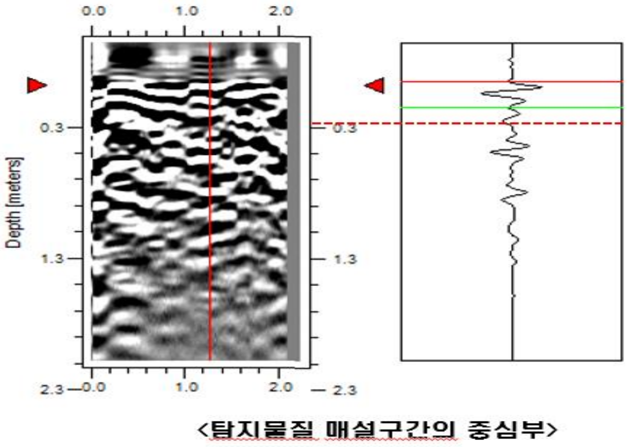


(f) Section with the detecting material (1.0m)

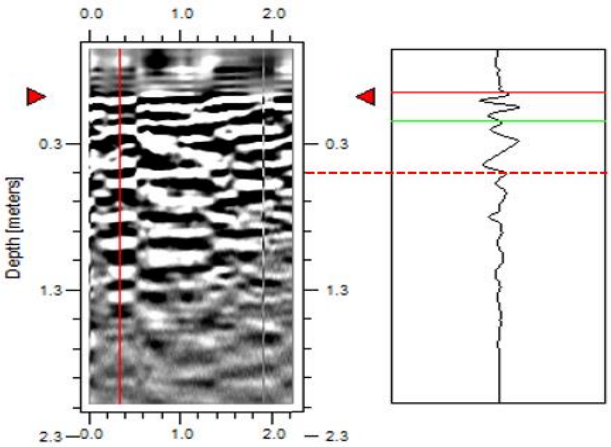
Figure 4. GPR Detection Results - EMI Sheet



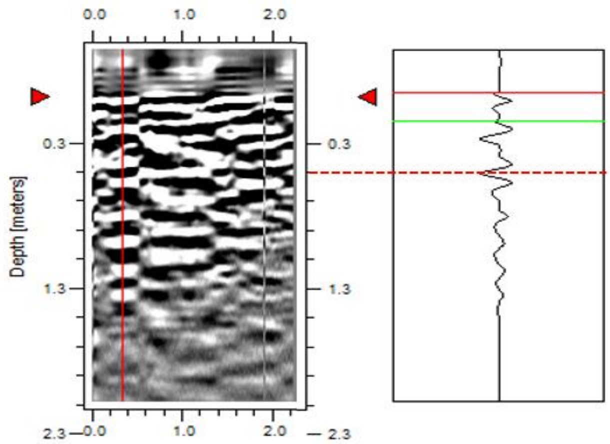
(a) Section without the detecting material (0.25m)



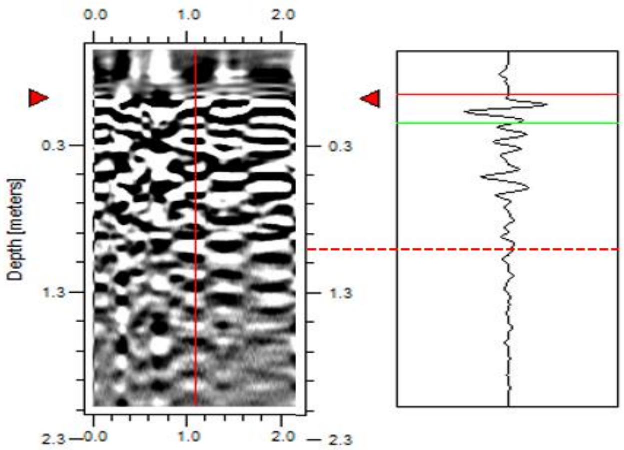
(b) Section with the detecting material (0.25m)



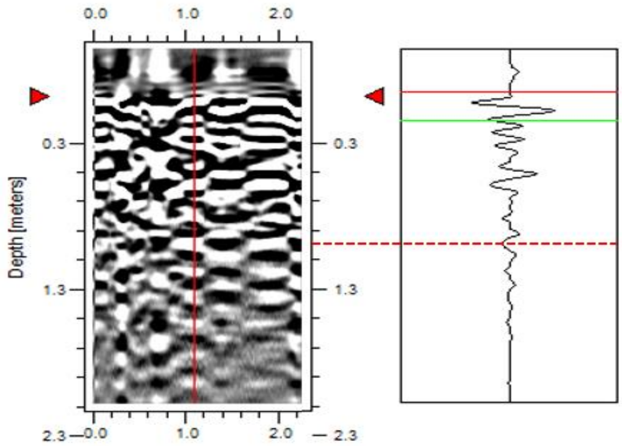
(c) Section without the detecting material (0.5m)



(d) Section with the detecting material (0.5m)

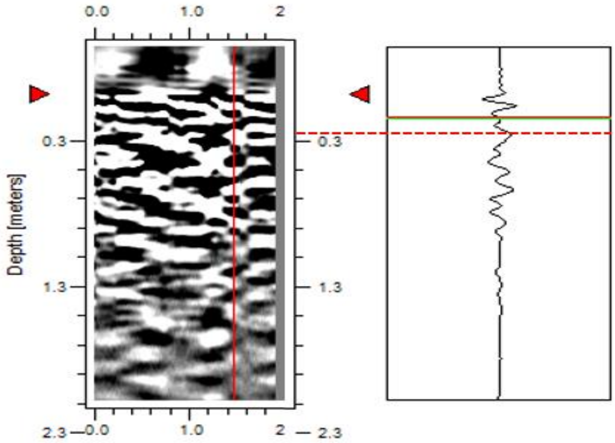


(e) Section without the detecting material (1.0m)

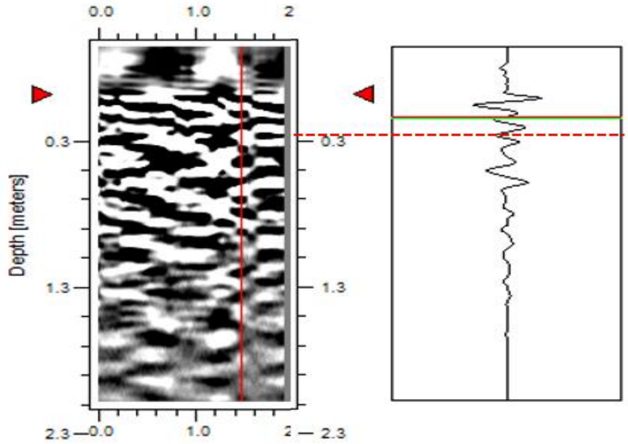


(f) Section with the detecting material (1.0m)

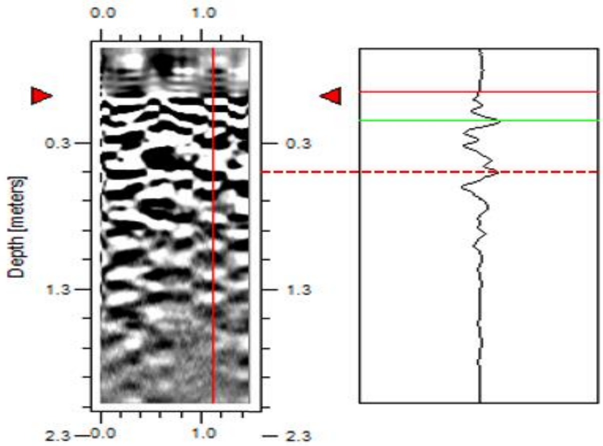
Figure 5. GPR Detection Results - EMI Paint



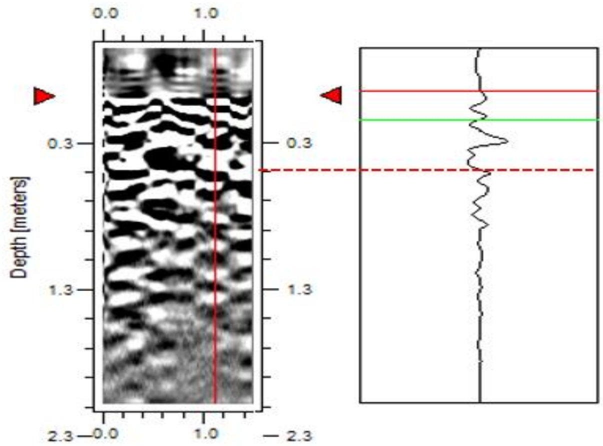
(a) Section without the detecting material (0.25m)



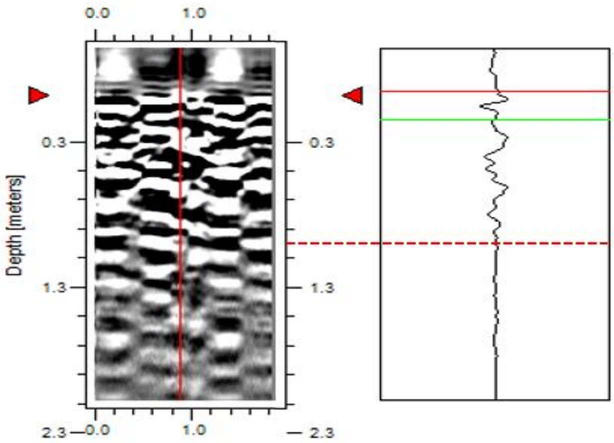
(b) Section with the detecting material (0.25m)



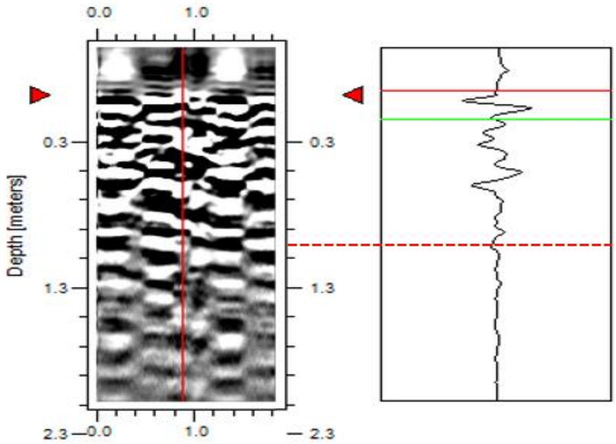
(c) Section without the detecting material (0.5m)



(d) Section with the detecting material (0.5m)



(e) Section without the detecting material (1.0m)



(f) Section with the detecting material (1.0m)

Figure 6. GPR Detection Results – Ferronickel slag

5 CONCLUSION

In this study, the field tests were conducted using EMI sheet, EMI paint, and ferronickel slag in order to confirm the applicability of GPR detection according to the types of detecting material buried in underground. The test results confirmed that the application of the detecting material was possible according to the restored method of cavity because the all detecting materials can be utilized for the application tthe GPR detection. However, it confirmed that the experiment is required depending on various soil conditions and the durability of the detecting material because the result of GPR detection is derived from the permittivity.

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