Detection And Characterization Of Buried Objects Using Seismic Reflection Technique

Muhammad Nur Hidayat ZAHARI, Sr Saiful Wazlan bin WAHAB, Aziman MADUN, SrAzlim Khan bin ABD. RAOF KHAN, Samsul Haimi DAHLAN and Dato' Sr Mohd Noor bin ISA, Malaysia

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SUMMARY

The technique of ground penetrating radar (GPR)possess somemeasurement limitations due to the uncertainties of the ground's electromagnetic (EM)propagation velocity valuesand the wave is prone to be interfered with its surrounding materials,in whichdirectly affectsthedetection accuracy. Thus,reflection method using seismic waveis suggested in this work to overcome this limitation especiallyfor the detection and characterizationof buriedobjects underground. An experimental workswas carried out to verify viabilityof this method. In this case, a plastic pipe with diameter of 0.16 m was buried 0.3 m from the ground surface and was used as the test object. Through this work, the seismic reflection data coming from several seismic sensor probes were gathered and translated into thetwo dimensional (2D) and three dimensional (3D) underground'stomographic profile. Based on our results, it suggested that this approach havegood potential ofunderground object detection capability (metal and non-metal) with accuracy of around 88%. In addition, it enable users to approximate the dimensions of the buried object almost accurately. This study open up possibility of using seismic reflection technique as an option for detection and characterizations of buried objects underground. Thus, it can be used as an alternative technique by the Department of Survey and Mapping Malaysia for underground pipe line detection. Further studies are still needed for this method to be used on detecting other type of underground utilities regardless of what they were made of, such as fiber optics and power cables.

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1. INTRODUCTION

Ground penetrating radar (GPR)methodis commonly used in utility detection. However, GPR is sensitive to the parameters of permittivity, conductivity and magnetivity of the ground. For instance, the utility buried below the groundwater table, under the reinforced concrete floor/slab and surrounded with the magnetic mineral resulted very low energy of the electromagnetic wave reflected back to surface due to the most of electromagnetic energy dispersed in the ground. As a result, the buried utility is unseen in the radargram. Undetected underground utility can delay construction operations. The leakage pipes beneath a road or underneath an existing property can lead to serious accidents and structural damages. For example,the leakage pipe was undetected in early stage and thus, causing the landslide tragedy of Bukit Antarabangsa, Ulu Klang, Kuala Lumpur Malaysia in December 2008 as shown in **Figure 1**. The surface depression is an earlier stage of indicator of water leakage events underneath. Therefore, detection and characterization of the pipe under the civil engineering structures is very important to avoid any casualties. The water pipe presents a unique anomaly due to the difference in physical properties between the surrounding geologic medium (Sloan, Cudney et al. 2016, Madun, Tajuddin et al.2016). The contrasts in wave velocity, stiffness and density between pipe and ground are three important principles for selectioninseismic reflection method to overcome the limitation of GPR method. For the past few years, several studies have been undertaken to test the seismic methods for detecting deep subsurface anomalies based on compressive wave reflection (Royal, Rogers et al. 2011, Buckley and Lane 2012, Mohanty 2011, Inazaki, Yamanaka et al.2004, Steeples and Miller 1988, Steeples and Miller 1987, Branham and Steeples 1988, Hunter, Pulan et al. 1984). This method is expected to provide information with greater resolution in the lateral dimension and can therefore be used to obtain a qualitative assessment of the ground properties (Song 2015, Madun, Jefferson et al. 2010). However, none of them adopted technique for the detecting the shallow object such as water pipe. In this study, the seismic-reflection equipment was developed to record the compressional wave (P-wave) propagation into the ground. The impact hammer generates the compressional wave when strikes to the ground and wave is reflected to the surface when meets a different ground properties of soil layers or pipes. In this paper, an experimental field study is performed to investigate the buried pipe with known depth and size. The cylinder shape pipe at size of 0.16 m was buried at 0.3 m depth. The characteristic of reflected wave was investigated with objectives of detection and characterization of the pipe.

Figure 1:The leakage pipe had caused the landslide tragedy at Ulu Klang, Kuala Lumpur, Malaysia.

2. REFLECTION CONCEPT

Reflections of seismic signals are detected using series of sensors that are placed and arranged accordingly on the ground. The direction of the propagating signals (eg. reflection and refraction)are affected by the medium such as the air, soil, or rock (Zahari, Dahlan and Madun 2015). Reflection method is much responsive to subtle changes, and able to provide fine details of the reflected area when used for imaging purposes.

The seismic wave reflection coefficient is directly proportional to the difference in acoustic impedance (Dvorkin, Guiterrez and Grana 2014) as in equation 2.1:

$$Z = \rho \cdot V \qquad (2.1)$$

Where ρ is defined as the density and V is the P-velocity or the S-velocity.

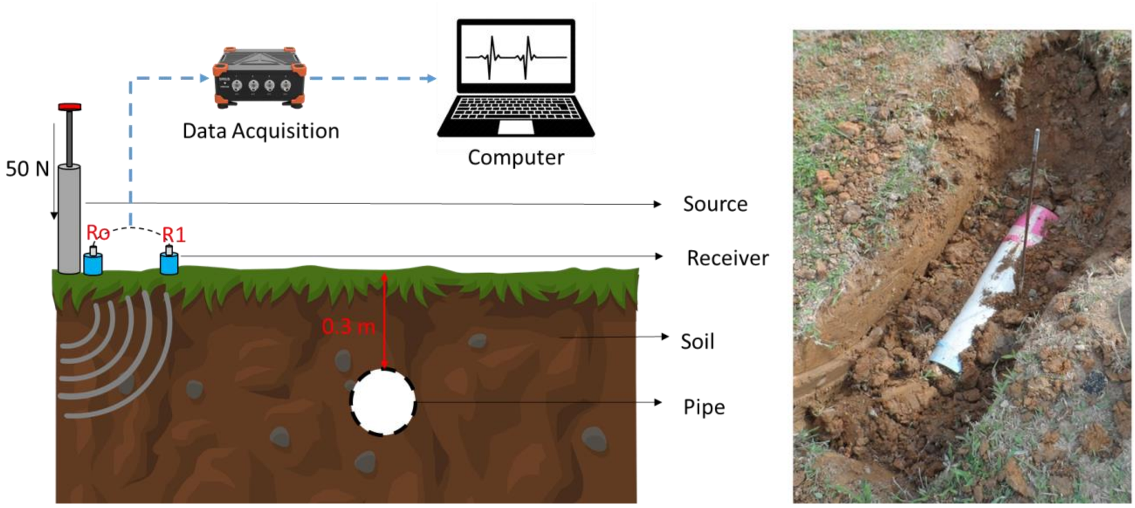
The reflection coefficient of normal incidence, R is defined by the following equation from Dvorkin et al., [14]

$$R = \frac{(Z_2 - Z_1)}{(Z_2 + Z_1)} = \frac{(\rho_2 V_2 - \rho_1 V_1)}{(\rho_2 V_2 + \rho_1 V_1)} \qquad (2.2)$$

Where Z_1 is the acoustic impedance in soil, and Z_2 is the acoustic impedance of pipe. The reflection coefficient can be both negative and positive. A positive coefficient means that most of the energies are reflected, and a negative coefficient implies that most of the energies are transmitted into layer 2. The acoustic impedance is used to determine the amount of energy that is transmitted between the layers.

3. TEST SETUP

The proposed technique consists of a hammer as an impact source, two seismic sensors,and a data logger for data acquisition. **Figure 2** illustrates the test set up where a hammer with uniform energy of 50 N force is used and applied in a close position from the source sensor R0. A computer is connected to the Data Acquisition unit (DAQ) to post process the data. Signal from the source sensor R0 acted as the reference at time t=0 and seismic sensor R1 as the receiver at time t. The amplitude of the reflection data is observed in time-domain. A plastic pipe cylinder with diameter of 0.16 m was used as the test object. It was buried 0.3 m from the ground surface as shown in **Figure 2(b).** The spacing between two seismic sensors i.e. source sensor (R0) and receiver sensor (R1) was kept constant 0.1m apart. This pair of sensor was moved along a straight line passing across the test area where the object was buried. Impact source (hammer) was applied and reflection data was measured at every 0.1m movement as illustrated in **Figure 3**. In this case data was gathered from 10 shot points.



(a) **(b)**

Figure 2: (a)Illustration of equipment setup and (b) the buried pipe

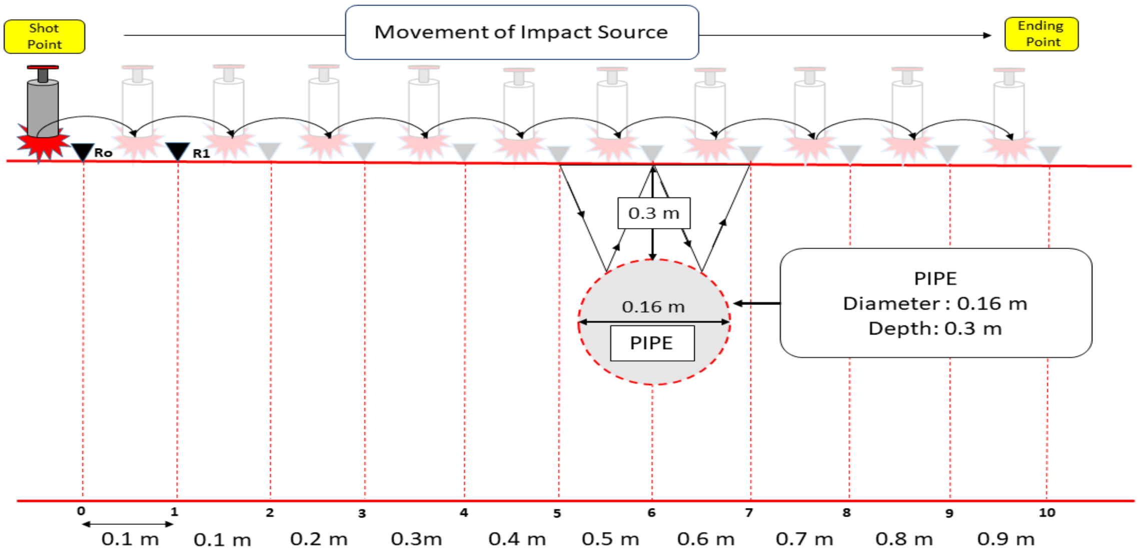


Figure 3: Illustration of the seismic source (R0) and accelerometer (R1) 10 movements at distance of 0.1 m each.

4. RESULT AND DISCUSSION

The soil density at the buried pipe was tested using core cutter method based on BS1377-1990 in-situ density test at 1780 kg/m^3. The compressive wave velocity is determined using three accelerometers at 0.1 m spacing and seismic source at 0.1 m from first accelerometer. From the first arrival wave that captured by the accelerometers, the compressive wave velocity was 455 m/s. The 10 shot points seismic wave data captured by the accelerometer R1 were gathered. The reflection waves were extracted and processed by using MATLAB software. The tomography plots are based on the combination of 10 seismic wave data points, which showed the wave displacement and depth along the horizontal 10 observation points.

The seismic reflection tests were conducted in two phases i.e. without and with the buried pipe were presented in 2-dimensional and 3-dimensional tomography as shown in **Figure 4** and **Figure 5** respectively. Both conditions showed that the accelerometer R1 detected the highest displacement up to 80 micrometer at 0.2m depth. It seems that at this depth, the combination of the body wave and shear wave superimposed forming the surface wave which has the highest displacement. For the case without pipe presented in **Figure 4(a)** and **Figure 5(a)**, the wave displacement decreased with depth at all points of 1 to 10. However, for the case with the buried pipe showed in **Figure 4(b)** and **Figure 5(b)**, the wave displacement decreased with depth at all the points except at point 6, where thelarge displacement at depth of 0.38 m and 0.55 m due to the increasing in the wave energy detected. The yellow area in **Figure 4(b)** and **Figure 5(b)** indicates high energy when the wave hit the top of the buried pipe, meanwhile the blue area indicates reflected wave due to the bottom of the buried pipe. The actual buried pipe diameter was 0.16 m and was successfully characterised by the reflected wave at 0.14 m with the accuracy of 88%.

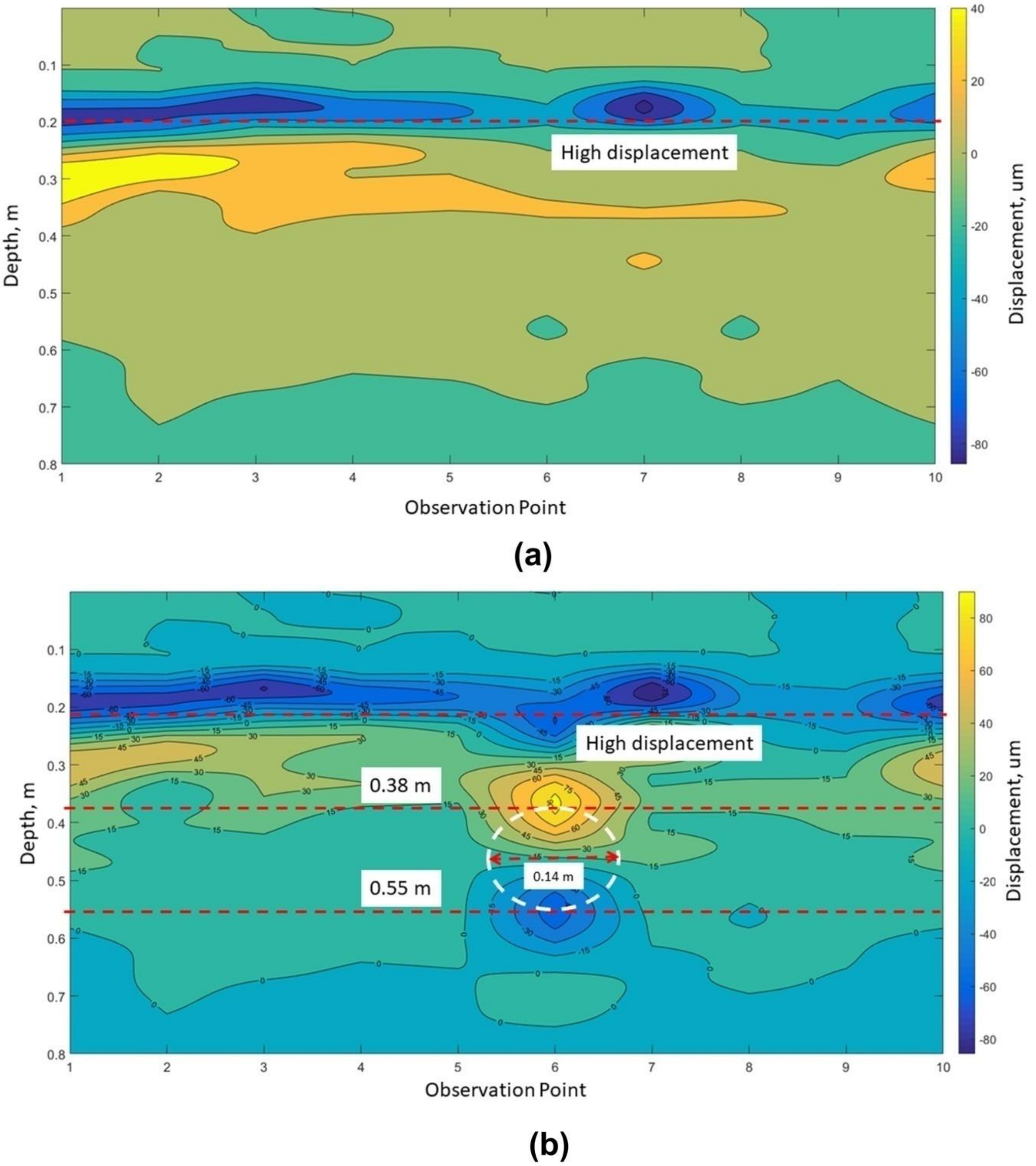


Figure 4: Two phases of the seismic reflection tests were conducted, (a) 2-dimensional tomography without the buried pipe, and (b) 2-dimensional tomography with the buried pipe.

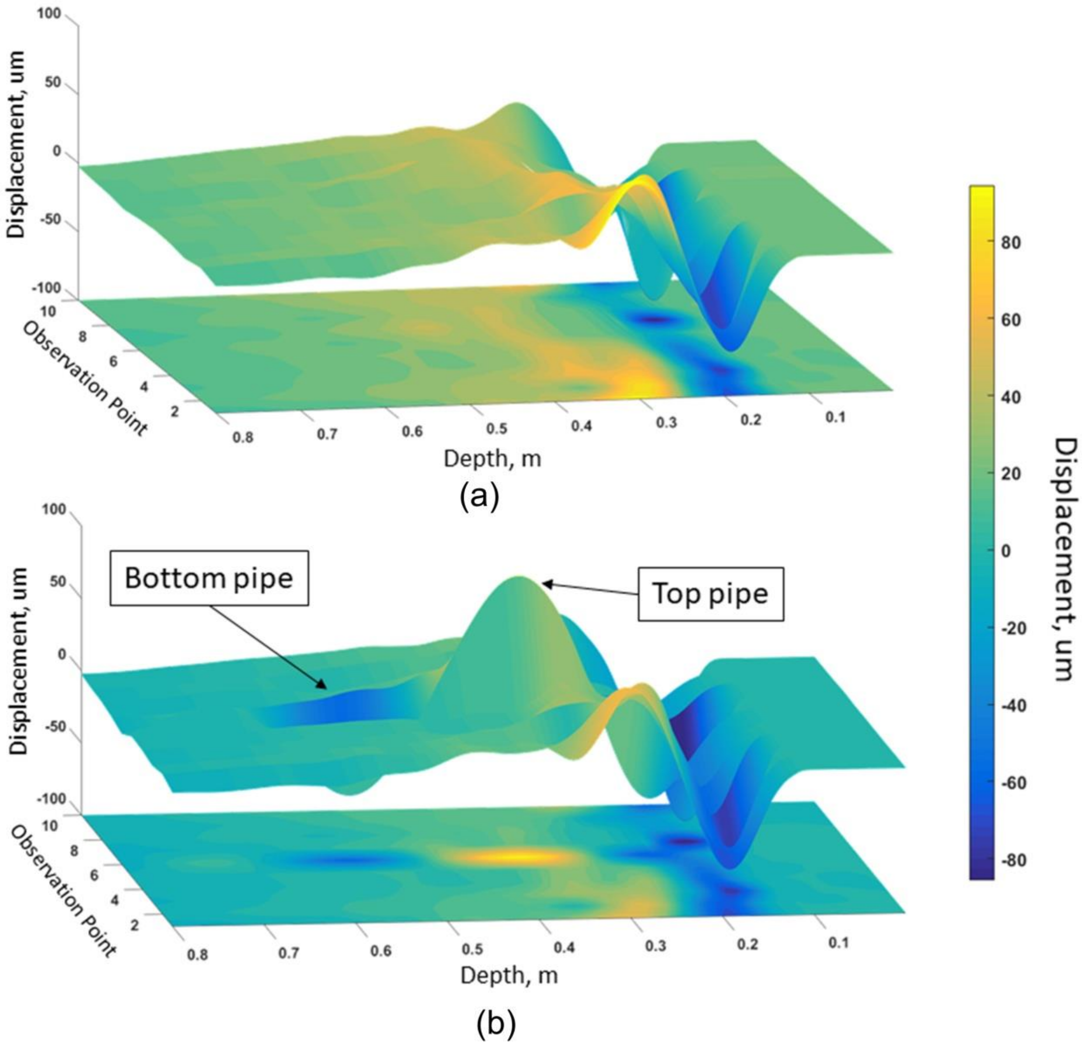


Figure 5: Two phases ofthe seismic reflection tests were analysed with; (a)3- and 2-dimensional tomography without the buried pipe, and (b) 3- and 2-dimensional tomography with the buried pipe.

5. CONCLUSION

In conclusion, the 2-and 3-dimensional tomography plot of displacement approach showed a great potential to detect and identify the diameter of the buried pipe with accuracy of 88%. The highest energy detected at the depth of 0.2 m due to the super positioned of the body wave and shear wave forming the surface wave which has the highest displacement. The energy pattern of the reflected wave at the top and bottom buried pipe can be visibly seen via 2- and 3-dimensional tomography plot at point no 6.

This study indicates that seismic reflection technique is consider acceptable for the buried pipe detection and characterisation. Thus, it can be used as an alternative technique by Department of Survey and Mapping Malaysia in underground pipe detection. However, further studies are still needed for the detection of other underground utility material such as fiber optic cable, water pipeline with various type of materials, sewerage pipeline, power cable etc.

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BIOGRAPHICAL NOTES

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