Jurnal Teknik Sipil & Perencanaan 26 (1) (2024) p 29 - 33

JURNAL TEKNIK SIPIL & PERENCANAAN

http://journal.unnes.ac.id/nju/index.php/jtsp/index

Interpretation of Ground Penetrating Radar (Gpr) to Determine the Depth of Pipe Objects in the Sandbox

Dwi Sri Wahyudi [a)] and Rini Kusumawardani[1, b)]

[1]*Civil Engineering, Faculty of Engineering, Semarang State University, Semarang City, Indonesia;*
dwisriwahyudi@students.unnes.ac.id
[1]*Civil Engineering, Faculty of Engineering, Semarang State University, Semarang City, Indonesia;*
rini.kusumawardani@mail.unnes.ac.id

[a)]Correspondence: dwisriwahyudi@students.unnes.ac.id

Abstract. Ground Penetrating Radar (GPR) is a non-destructive inspection technology that utilizes electromagnetic (EM) waves to map subsurface structures. This study focuses on estimating the diameter and depth of buried cylindrical objects, especially pipes, using GPR. This research was carried out through laboratory experiments using a box filled with dry sand. GPR data is processed using matGPR software to analyze hyperbolic reflections generated by buried objects. matGPR is software used for mathematical calculations of all three software. The speed of the EM wave is calculated based on the dielectric properties of the sand, and the depth and diameter of the pipe are estimated using a mathematical model derived from hyperbolic reflection. The results showed that the pipe depth estimate had a low error percentage, generally below 5%, which indicated high accuracy in GPR measurements, pipe A showed an estimated depth of 16.2 cm with the result obtained an error percentage of 1.8%, pipe B showed an estimated depth of 15.3 cm with the result obtained an error percentage of 1% and pipe C showed an estimated depth of 13.7 cm with the result obtained The error percentage is 2.2 %.The study concludes that GPR is an effective tool for estimating the depth of buried objects, especially in a controlled environment such as a sandbox. However, factors such as burial depth, pipe material, and dielectric properties of the medium can affect the accuracy of the measurement. Future research should consider using varied pipe materials and deeper burial depths to further validate the reliability of this method under field conditions.

Keywords : Ground Penetrating Radar (GPR), hyperbolic reflection, buried pipe, depth estimation, sandbox experiment.

BACKGROUND

Ground Penetrating Radar (GPR) can be used to detect the location of underground structures (Daniels, 2004). This method utilizes the principle that electromagnetic waves emitted from the surface to below the surface will be reflected at the surface boundary which has different electrical properties from the ground below the surface. Thus, this method can determine the location of surface boundaries and subsurface soil characteristics (Kanemitsu et al., 2024). The selection of the right antenna frequency depends on the project objectives (Burger, 1992). High frequencies produce higher resolution profiles at shallow depths, while low frequencies produce lower resolution profiles but can penetrate deeper (Ni et al., 2010). The use of GPR in civil engineering varies depending on the purpose of data collection, with each placing certain limitations on the design of effective GPR. For example, most buried pipes are within 1.5-2 m of ground level, but may have wide variations in size, materials (metallic or non-metallic), and environmental conditions, affecting the absorption and propagation speed of electromagnetic waves, as well as GPR

LITERATURE REVIEW

Ground Penetrating Radar (GPR) utilizes electromagnetic waves, which are the propagation of electric field vibrations and magnetic fields that are perpendicular to each other in the direction of their propagation. The basic principle of this electromagnetic wave utilization is to measure the response of the soil to the propagation of electromagnetic waves, which involve alternating currents and magnetic fields (Kearey et al., 2002).

The speed of wave propagation can be calculated or measured through several techniques. However, if there is a significant horizontal variation in the electromagnetic properties of the soil or the moisture content below the surface, then the calculated velocity may only be valid at one calibration point (ASTM D6432-11, 2011). Accurate measurement of target depth relies heavily on an understanding of the propagation velocity of electromagnetic waves in the soil, which vary greatly and can lead to errors in depth estimates (Benedetto & Pajewski, 2015).

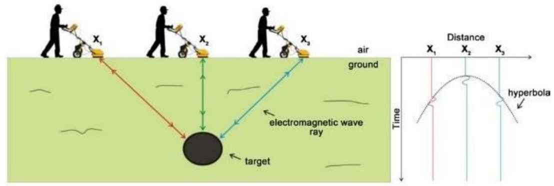

FIGURE 1. shows the position of the GPR profile and the resulting hyperbolic (Poluha et al., 2017)

The propagation speed of electromagnetic waves is influenced by soil type and moisture content, which often varies with depth from the surface depending on the nature of the rock mass (Jol, 2009). The waves reflected by buried objects have different electrical properties than ground. The time from signal transmission to reception (reflection time) is measured. When the instrument is scanned vertically into a buried pipe, the detected image appears as an upward convex satellite dish. Depth is estimated as the distance from the ground level to the highest intensity point at the parabolic peak. The depth of the pipe is calculated as follows (Kanemitsu et al., 2024):

$$\mathrm{D} = \frac{1}{2} \times (\mathrm{Vm.T}) = \frac{\mathrm{c}}{2\sqrt{\mathrm{\varepsilon r}}}\ .\mathrm{T} \qquad (1)$$

Information:

D = Depth of object (pipe) (m),
T = Reflection time of the target(s),
c = speed of Light in free space (3.00 x 108 m/s),
εr = relative dielectric constant,
Vm = velocity of electromagnetic waves (*velocity*) (m/s).

COMPONENT SYSTEM

The component system used in the GPR acquisition process consists of four main parts, namely *antenna*, *control unit, display unit,* and *power supply*. *Antennas* function as *transmitters* and receivers of waves that propagate below the surface. There are several types of *antennas* developed by Geoscanner, in the study using the 1500 GCB model. The control unit serves to convert the analog signal received from the antenna into a digital signal, which is then sent to the display unit. The control unit is compatible with the antenna model 1500 GCB, i.e. the Akula 9000C. There are two main applications for GPR users developed by Geoscanner, namely GAS XPC, GPRSoft. For matGPR, which is *open-source software* that can be used through MATLAB, this is a comparative result. Wooden boxes containing dry sand and 3 pipes that were embedded are a medium for data collection in the laboratory.

METHOD

Radar Reflection Profiling is a method in which antennas are moved simultaneously above ground level to collect data. In this method, the *two-way travel time* measured until it reaches the reflector is displayed on the vertical axis, while the distance traveled by the antenna during the scanning process is shown on the horizontal axis. In this way, information about the depth and position of the subsurface reflector can be obtained more clearly.

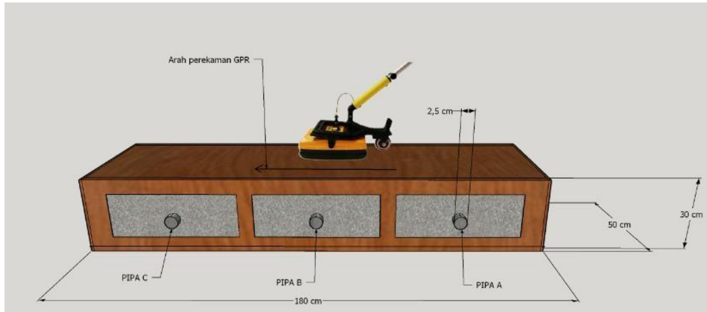

FIGURE 2. Illustration of GPR tool and sandbox and GPR data retrieval direction on sandbox

RESEARCH RESULTS

In this section, it explains the results and analysis based on the data processing that has been carried out. Data analysis was carried out in order to find out the estimated depth and pipeline in the sandbox. Data processing uses *matGPR* software.

Data processing results

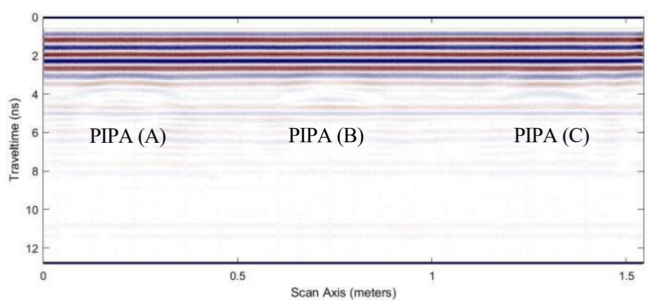

FIGURE 3. The results of the radar before the data are processed on matGPR (raw data) software

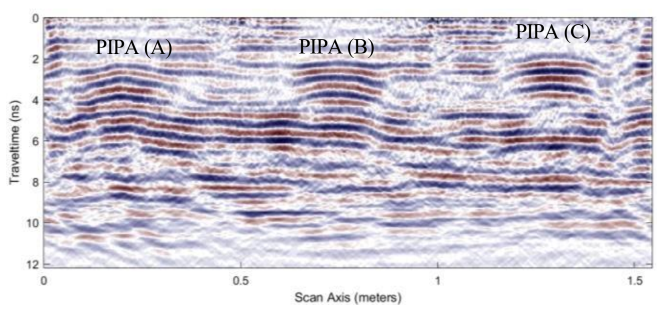

FIGURE 4. Radargram results after processing using matGPR software

Calculation of the estimated depth and diameter of the wooden box

TABLE 1. Results of depth estimation data for pipes A, B and C

Pipes	*Actual Depth (cm)*	*Actual Deeph (m)*	*Velocity (drysands) (m/ns)*	*Time*	*Estimated depth (m)*	*Estimated depth (cm)*	*Error %*
A	16,5	0,165	0,1278	2,54	0,162	16,2	1,8%
B	15,5	0,155	0,1278	2,40	0,153	15,3	1,0%
C	14	0,14	0,1278	2,14	0,127	13,7	2,2%

TABLE 2. Time number data results on pipes A, B and C

	Hyperbolic *time* value (ns)		
Pipe	Above	Bawah	Δt
A	2,54	2,70	0,165
B	2,40	2,57	0,168
C	2,14	2,31	0,169

CONCLUSION

It can be seen that the results of GPR data for depth estimation using existing equations can produce an error percentage below 5%. i.e. pipe A has an *actual* depth of 16.5 cm and processing with software shows an estimated depth of 16.2 cm with the result obtained an error percentage of 1.8%. Pipe B has an *actual depth of 15.5 cm and processing with software shows an estimated depth of 15.3 cm with* the result of an error percentage of 1 %. Pipe C has an actual depth *of 14 cm and processing with software shows an estimated depth of 13.7 cm with the result obtained an error percentage of 2.2 %. This indicates that both data collection and processing have good accuracy results. GPR is an effective tool for estimating the depth of buried objects, especially in a controlled environment such as a sandbox.*

PENAFIAN

This article aims to provide general information about civil engineering and is not professional advice. The author and publisher are not responsible for any errors, omissions, or repercussions of the use of this information. Always consult with the relevant engineer or expert before implementing the concepts discussed.

AVAILABILITY OF DATA AND MATERIALS

The data and materials used in this article are obtained from relevant and accountable sources. However, the author does not guarantee the accuracy, completeness, or novelty of the information presented. The use of the data and materials in this article is entirely the responsibility of the reader If required, the reader may contact the author for further information regarding the availability of data and related materials.

THANKS

Respectfully, I would like to express my deepest gratitude to the Soil Mechanics Laboratory of Semarang State University for the guidance, knowledge, and direction provided during the preparation of this article. The support and insights provided are invaluable in understanding and developing the topics discussed, so that they become valuable provisions for me and other colleagues in my academic and professional journey ahead. Again, thank you for all the help and dedication given.

I would also like to thank my friends for the support, discussion, and enthusiasm given in completing this article. The togetherness and cooperation that exists is very meaningful in this academic journey.

REFERENCE

[1] ASTM D6432-11.: *Standard Guide for Using the Surface Ground Penetrating Radar Method for Subsurface Investigation* (2011)

[2] Benedetto, A. and Pajewski, L. (2015) *Civil engineering applications of ground penetrating radar*, *Springer transactions in civil and environmental engineering*. https://doi.org/10.1007/978-3-319-04813-0.

[3] Burger, H.R. (1992) *Exploration geophysics of the shallow subsurface*, *Prentice Hall eBooks*.http://library.uny.ac.id/sirkulasi/index.php?p=show_detail&id=5542& keywords=.

[4] Daniels, D.J. (2004) Ground penetrating radar. IET.

[5] Jol, H.M. (2009) Ground Penetrating Radar Theory and Applications, Elsevier eBooks. https://doi.org/10.1016/b978-0-444-53348-7.x0001-4.

[6] Kanemitsu, T., Morifuji, Y. and Kubota, K. (2024) 'Estimation of buried pipe depth in an artificial soil tank using ground-penetrating radar and moisture sensor,' Journal of Applied Geophysics, 220, p. 105283. https://doi.org/10.1016/j.jappgeo.2023.105283.

[7] Kearey, P., Brooks, M. and Hill, I. (2002) An introduction to geophysical exploration. John Wiley & Sons.

[8] Shihab, S., & Al-Nuaimy, W. (2005). Radius estimation for cylindrical objects detected by ground penetrating radar. Subsurface Sensing Technologies and Applications, 6(2), 151–166. https://doi.org/10.1007/s11220-005-0004-1

[9] Ni, S.-H. et al. (2010) 'Buried pipe detection by ground penetrating radar using the discrete wavelet transform,' Computers and Geotechnics, 37(4), pp. 440–448. https://doi.org/10.1016/j.compgeo.2010.01.003.