Journal of Materials Science Research and Reviews

Volume 6, Issue 4, Page 913-917, 2023; Article no.JMSRR.110331

Application of Ground Penetrating Radar in Quality Inspection of Water Transmission and Diversion Projects

Yuxuan Li [a*]

[a] *North China University of Water Resources and Electric Power, Zheng Zhou, 450046, China.*

Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

Article Information

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/110331

Mini-review Article

Received: 09/10/2023
Accepted: 12/12/2023
Published: 16/12/2023

ABSTRACT

In order to further verify the accuracy of Ground Penetrating Radar in practical engineering, this article takes the quality inspection of a water conveyance tunnel in Henan as an example. By analyzing and verifying the defect images such as non compaction and voids in the inspection results, the accuracy of Ground Penetrating Radar detection in practical engineering is given, providing a basis for the effective application of Ground Penetrating Radar in engineering practice.

Keywords: Ground penetrating radar; quality inspection; practical engineering.

1. INTRODUCTION

In recent years, with the development of the water conservancy industry, the characteristics of long-distance and large-span water transmission and transfer projects have become increasingly evident.In order to ensure the healthy and safe operation of water conservancy projects, regular quality testing is particularly important [1-4]. The quality inspection methods for hydraulic engineering include drilling core method, rebound method, ultrasonic method, etc. In the quality inspection of hydraulic engineering, although the results of the drilling core method

**Corresponding author: Email: l1047555078@qq.com;*

are accurate, it has a certain degree of destructive effect on the original concrete structure and cannot be detected on a large scale; The rebound method is influenced by many factors in water transmission and diversion projects, and the accuracy of its results needs further verification [5].The detection results of the ultrasonic method are accurate and non-destructive, but when the ultrasonic method detects steel bars, it will be strongly interfered by the steel bars, which will also affect the judgment of the results. Therefore, it is particularly important to choose a detection method that has accurate detection results, high detection efficiency, non-destructive, and strong anti-interference.

The Ground Penetrating Radar method is a physical exploration method that utilizes the different reflection characteristics of electromagnetic waves by different media to detect the internal structures and defects of the media. This method has the characteristics of fast detection speed, high accuracy of detection results, and wide detection range, and can almost meet various requirements for quality inspection of water transmission and diversion projects, including lining thickness, protective layer, steel bar spacing, void, backfill grouting compactness, and surrounding rock fragmentation [6-9].

2. INTRODUCTION TO GROUND PENETRATING RADAR TECHNOLOGY

2.1 Composition of Ground Penetrating Radar

Ground penetrating radar mainly consists of five parts: host (main control unit), transmitter, transmitting antenna, receiver, and receiving antenna [10]. The host is a collection system that sends transmission commands to the transmitter and reception commands to the receiver (including start and end time, transmission frequency, repetition rate, and other parameters). The function of the transmitter is to emit electromagnetic waves underground according to the commands of the host. The function of the receiver is to start data collection based on commands from the host. The transmitting and receiving antennas appear in pairs and are used to transmit and receive electromagnetic waves reflected underground.

2.2 Working Principle of Ground Penetrating Radar

The working process of ground penetrating radar: The transmitting antenna emits high-frequency and short pulse electromagnetic waves underground. When the electromagnetic wave passes through an interface with electrical differences during underground propagation, some of the electromagnetic wave energy is reflected back, while the other part continues to transmit forward [11]. The reflected electromagnetic wave is recorded by the receiving antenna, and the two-way travel time and waveform amplitude characteristics of the reflected wave of the target body are obtained The reflected electromagnetic wave information of the target body, such as the geometric changes of the same phase axis, will change with the electrical properties and geometric changes of the target body. By analyzing this feature information, the structural characteristics and spatial distribution position of the target body can be detected.

The calculation formula for the travel time t of electromagnetic waves is:

$$t = \sqrt{4h^2 + x^2} \Big/ v \tag{1}$$

In the equation:

t: The travel time of electromagnetic waves, in ns, 1ns=10^{-9}s;

h: Detect target depth in meters;

x: The distance between the receiving antenna and the transmitting antenna, in meters;

v: The velocity of electromagnetic waves in the medium, in m/ns, is calculated using the formula:

$$\mathrm{v} = c \Big/ \sqrt{\varepsilon_r} \tag{2}$$

In the equation:

c: The propagation speed of electromagnetic waves in vacuum, c=0.3m/ns;

ε_r: Relative dielectric constant.

2.3 Ground Penetrating Radar Detection Depth

The detection depth of ground penetrating radar is directly affected by the central frequency antenna of the ground penetrating radar. The higher the frequency of the central antenna, the smaller the detection depth and the higher the accuracy; The smaller the frequency, the greater the detection depth and the lower the accuracy. The detection depth corresponding to the center frequency of the ground penetrating radar antenna is shown in the Table 1.

Table 1. Detection depth corresponding to antenna frequency

Antenna frequency	detection depth/m
100MHz	4～25
400MHz	1～4
900MHz	0.5～1
1500MHz	0.2～0.5

2.4 Response of Ground Penetrating Radar to Different Media

2.4.1 Concrete

The main component of the lining is concrete. Concrete is made by mixing water, cement and aggregates in a certain proportion. Generally speaking, the reflection waveform of the detection results of fully mixed concrete will be relatively stable and continuous. When the mixing is not sufficient, the concrete may experience non compaction. When the phenomenon of non compaction occurs, the reflection waveform will be more chaotic. By analyzing the degree of disorder, the compactness of concrete can be determined.

2.4.2 Steel reinforcement

Steel bars are usually placed in the lining. Due to the fact that steel bars are good conductors, there will be a total reflection phenomenon when electromagnetic waves pass through the interface between the lining and steel bars. The characteristic graph of steel bars on radar profiles is generally represented as a hyperbola, and the position of the arc top is extremely similar to the position of the steel bars.

2.4.3 Surrounding rock

Unlike lining, the surrounding rock is mostly irregular and has relatively weak reflections. However, due to the significant difference in material properties between the concrete and surrounding rock in the lining, the ground penetrating radar detection results will have obvious layered interfaces, which can be used to determine the thickness of the lining.

2.4.4 Air layer

When using geological radar to detect lining, if there is an air layer, an abnormal reflection wave will appear. On the radar profile, it will appear as a reflection wave in the opposite direction, with strong reflection and alternating white and gray phases.

3. ENGINEERING EXAMPLES

This project is a water conveyance tunnel in Henan. The tunnel body is lined with C50W8F100 concrete segments, with a total of 9852 rings. Each ring of the concrete segments is equipped with 4 hexagonal honeycomb shaped segments, including standard A segments on both sides, bottom segment B, and top segment C. The inner diameter of the segment ring is 3.5m, the width of the segment ring is 1.2m, and the thickness is 0.3m

The tunnel of this project is a circular tunnel, supported by segments, pea gravel grouting body, and surrounding rock. The thickness of the segments is 30cm, and the thickness of the pea gravel grouting body is 10-15cm, with a detection depth of about 45cm.

3.1 Radar Image of Non Dense Defects

From the Fig. 1, it can be seen that the interface between the pipe segment and the pea gravel grouting body is obvious. Above the boundary is the pipe segment, and below it is the pea gravel grouting body. The radar reflection signal of the pea gravel grouting body below the segment is strong, indicating that there are quality defects in the pea gravel grouting body. The reflection signal of the steel bars inside the pipe segment is strong, presenting a hyperbolic characteristic image, and the top of the hyperbolic curve is the position of the steel bars. The red box shows the radar image of quality defects in the pea gravel grouting body. The reflected signal at this location is strong, the waveform is chaotic, presenting fragmented and discontinuous gray white alternating images, indicating that the defect here is not dense. And there are also

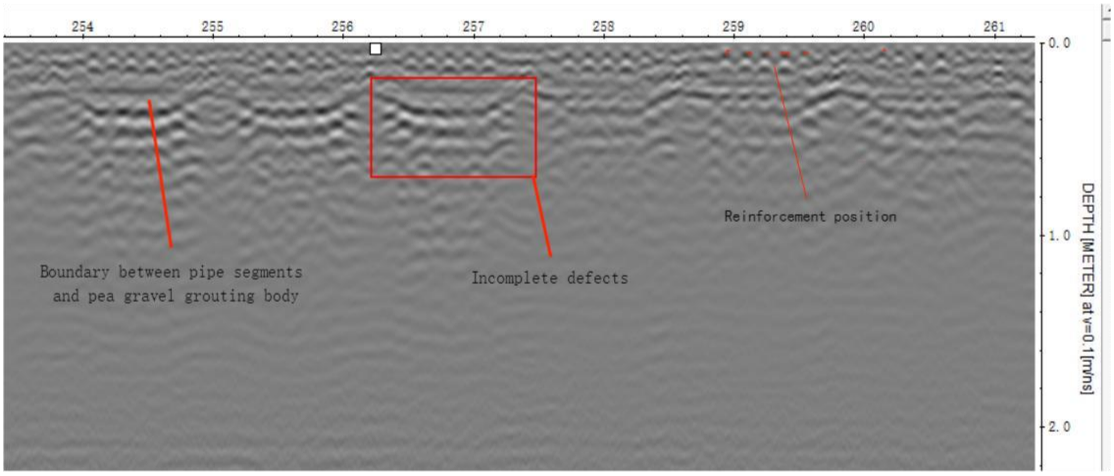

Fig. 1. Radar image of incomplete defects

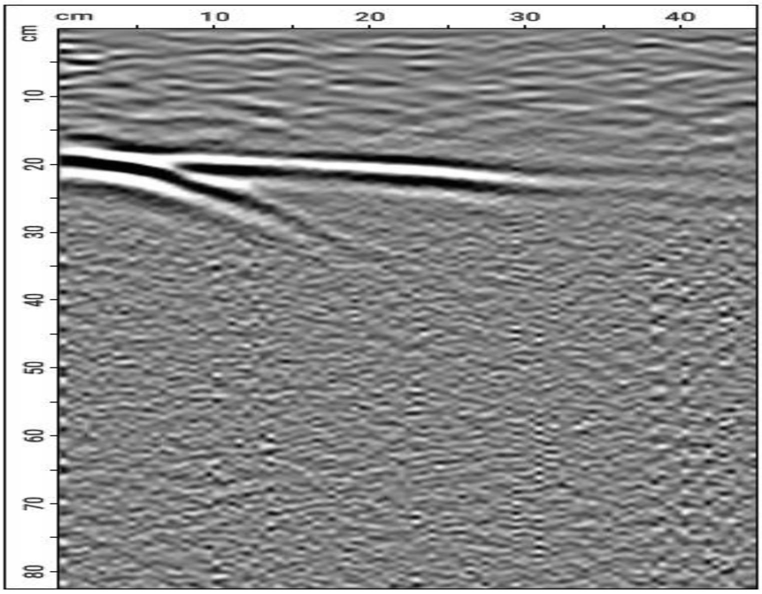

Fig. 2. Radar image of void defect

varying degrees of non compaction at the left arch waist of the adjacent two ring pipe segments. At the same time, according to the image, the depth of the non dense defect here is approximately 0.45m. Due to the high frequency of the selected central antenna, the detection depth is too small to see the interface between the pea gravel grouting body and the surrounding rock in the image.

3.2 Void Defect

The Fig. 2 shows the radar image of the void defect. From the figure, it can be seen that there is a radar reflection signal at a depth of 0.2m that far exceeds the density of the defect. The reflected signal here is extremely strong and there are continuous gray white alternating images, indicating the presence of void defects at a depth of 0.2m, and the void length is about 0.3m. The waveform of the image above the void defect is relatively stable but intermittent, indicating a slight lack of compaction.

4. CONCLUSION

Through the above engineering practice, it can be seen that the detection results of ground penetrating radar for quality defects in water tunnels are accurate. When selecting a suitable central antenna, data such as the position and spacing of steel bars, defect types and ranges can be obtained. With the development of technology and the demand for water conservancy engineering construction, the application of ground penetrating radar technology, a detection method with many advantages, will become more and more mature and extensive Cheng quality to escort.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Mulin Yuan, Maogan Dong, Pan Ming, etc. Application of ground penetrating radar in quality inspection of tunnel lining for urban water diversion and supply project in Central Jilin Province. Journal of Water Resources and Construction Engineering. 2021;19(03):99-104.
2. Liyue Song.Application of ground penetrating radar detection technology in water conservancy engineering inspection. Heilongjiang Water Conservancy Science and Technology. 2022;50(3): 171-174.
3. Tao Ding. Application of ground penetrating radar technology in quality inspection of water conservancy engineering [J]. Heilongjiang Water Conservancy Science and Technology. 2022; 50(2):164-166.
4. Deshan Feng, Yuxin Liu, etc. Special Issue on Ground Penetrating Radar: Theory, Methods, and Applications[J].Applied Sciences. 2023;13(17).
5. Hao Ding. Application of ground penetrating radar technology in water conservancy engineering testing[J].Water Conservancy Planning and Design. 2018;(06).
6. Yunhua Zhu. The application of ground penetrating radar in tunnel detection[J]. Journal of Water Resources and Construction Engineering. 2015;13(02):140-143.
7. Yongfeng Yan. Application of ground penetrating radar in quality detection of hollow lining in water conservancy engineering tunnels [J]. Guangdong Water Resources and Hydropower. 2023;(02):15-19.
8. Peng Xiong.Ground penetrating radar and its application in quality inspection of hydraulic engineering [J]. Sichuan Cement. 2023;(02):156-159.
9. Qing Wang. Application of Ground Penetrating Radar in Waveform Recognition of Tunnel Detection Technology[J]. Engineering Technology Research. 2017;(9):126-128.
10. Qiang Liu, Chao Wang.Research on the Application of Ground Penetrating Radar Technology in Quality Inspection of Water Conservancy Engineering [J]. Engineering Technology Research. 2022;7(20):20-22.
11. Gaohang Lv, Jian Liu, Quanyi Xie etc. Rapid identification and location of defects behind tunnel lining based on ground-penetrating radar[J]. Journal of Performance of Constructed Facilities. 2023;37(4).

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/110331