Using Georadars for Evaluating the Thickness of a Concrete Layer

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Abstract. At present, georadiolocating research is actively used in various fields of engineering surveys. In the article, we discuss the scan for concrete structures and assess their thickness and condition using this method. The principle of operation of radar is based on the emission of electromagnetic pulses of the radio range and the reception of a signal reflected from the interface of the media (the boundary between the layers of the studied soil stratum having sharply different electrophysical properties). The aim of the study is to accurately determine the location and layout of the reinforcing bar, tension cables, beams, pipelines, voids, and plates. The presence of metallic objects in the studied strata is a valuable identification feature, and metal objects known to be located are convenient marking elements of the section.

1. Introduction

Ground penetrating radar is a geophysical imaging method that is actively used for underground research and monitoring. It is widely used in solving various problems in various industries - construction, geology, archeology, forensics, etc. [1-7]. Working on the X-ray principle, but much safer, it is an effective method of obtaining subsurface images of the contents inside any solid material (soil, concrete, asphalt, etc.) [8-14]. Ground penetrating radar covers a wide area in a relatively short period of time for specific evaluation studies. With the latest advances in hardware and software, concise real-time analysis can be performed on site [15-17].

In this study, we used two media, soil, to find a metal container and concrete.

In the first case, we searched for a buried dilapidated tank for storing fuel oil. In the second, we evaluated the state and capacity of the concrete coating of the constructed sludge collector.

We used the MALÅ Easy Locator HDR GPR, with a screened antenna frequency of 450 MHz.

The purpose of the study is to detect a dilapidated underground tank, as well as to assess the condition and power of the concrete coating using MALÅ Easy Locator HDR equipment with a shielded antenna frequency of 450 MHz.

2. Method of work

2.1. Method of searching for a buried dilapidated fuel oil storage tank

For the first case, the work methodology was as follows: we carried out the GPR survey by the method of profile sounding using an antenna unit with frequencies of electromagnetic pulses of 450 MHz, which allowed us to achieve the optimal combination of the depth of research up to 6.5 meters and resolving power of 4-8 cm.
In total, we made 30 GPR profiles with a total length of 600 rm. To improve the display of the radar data, we processed the obtained research results using the processing program “Object Mapper”, by the company “MALÅ”.

The decrypted buried objects and areas of disturbed soil bedding were marked on the radiogram line in the form of notation conventions. Cylindrical objects - red circles, disturbed soil occurrence - red rectangles.

2.2. Method for assessing the condition and capacity of the concrete coating of the constructed sludge accumulator

We evaluated the thickness of the concrete layer of the bottom of sludge collectors (second case) using the MALÅ Easy Locator HDR GPR, with a screened antenna frequency of 450 MHz. We performed a series of profiles with GNSS binding. To calibrate GPR, we carried out a series of test profiles on dry concrete structures with a known concrete capacity and reinforcement scheme in advance. The interpretation of the profiles showed that the interface between the concrete and the underlying sand is indistinct. This is due to a similar relative dielectric constant of concrete and sand with similar humidity. Also, the situation was complicated by the insignificant thickness of the concrete layer (10-20 cm), comparable with the resolution of the used antenna (4-8 cm). On the radar graph, the reflected and direct waves were practically superimposed, which necessitated the use of a large number of filters.

3. Results

3.1. Search results for buried dilapidated fuel oil storage tank

As a result of the conducted georadar survey of the buried dilapidated tank for storing fuel oil, the following conclusions can be drawn:

1. The upper part of the section is composed of technogenic soils (displaced sands with rubble and construction waste) with a thickness of up to 0.8 m.
2. The base soils are represented by rocks of a sandy composition.
3. Ground water at the time of the survey at the site within the survey depth was not found.
4. The high amount of construction waste and destroyed utilities in the sections makes it impossible to determine clear contours of the fuel oil storage, only the probable area of its location is highlighted (indicated with a red dotted line in Fig. 1).

Figure 1. Probable location of the fuel oil storage facility.
5. Identified objects of a rounded section correlate with the lines of networks indicated on the general plan. The depth is 0.3-1 m (Fig. 2).

![Figure 2. An example of locating communications on a radar graph.](image)

6. In sections 29 and 30, in the area of the visible soil failure, we identified areas of disturbed bedding that spatially coincide with the well of the communication network indicated on the general plan (Fig. 3).

![Figure 3. Areas of disturbed ground occurrence](image)

7. We revealed objects shielding the radio signal, lying at a depth of 0.2 m, presumably metal sheets.

![Figure 4. Objects that screen the radio signal](image)
8. The estimated area of the tank is 108 m². To accurately detect the contours of the reservoir, we recommended to make test pits 1.2 m deep along and across the selected area. The most convenient are the lines of sections 12, 20, and 22 (Fig. 5). We recommended making the first pit in the direction of AB until the eastern wall of the tank is discovered. Then moving to BA direction until the western wall is discovered. Then adjusting VG and DE pits depending on the results of AB pit. The estimated total pit length is 51 running meters.

![Figure 5. Strip pits for precise detection of the contours of the container.](image)

9. When making AB pit, the eastern edge of the wall was found at a depth of 1.2 m. Further pits were made based on this contour (Fig. 6).

![Figure 6. The proposed location of the tank at the site of laying pits.](image)
10. Within the study area (southern part of the storage), the tank ceiling is destroyed, the walls are also partially collapsed, they are found fragmentary, at a depth of 1.2-1.8 m.

11. Communication networks (electric cable) were laid on top of the tank at a depth of 0.7-0.8 m with a protective layer of plastic tiles at a depth of 0.5-0.6 m. The contours of the exposed sections of the cable and those expected from the results of work are shown in Fig. 6.

12. The northern part of the storage is in better preservation, the upper part of the wall was opened all along at a depth of 0.7-0.8 m (Fig. 7).

![Figure 7. Opened part of the storage.](image)

13. The storage has a circle shape with a radius of 8-8.5 m.

14. The depth of the bottom of the tank is not possible to determine.

3.2. The results of the evaluation capacity of the concrete layer
When assessing the thickness of the concrete layer of the bottom of the slurry collectors (the second case in the study), the only sufficiently significant diagnostic feature was the metal reinforcement located according to the standards at the lower boundary of the concrete layer (Fig. 8).

![Figure 8. Diffraction parabolas.](image)
Orientating to reinforcement over the entire area of the sludge storage during decryption, we evaluated the capacity of the concrete coating and obtained the corresponding cartogram (Fig. 9).

![Cartogram of concrete layer capacities.](image)

Figure 9. Cartogram of concrete layer capacities.

Thus, the presence of metallic objects in the studied strata is a valuable identifying feature, and metal objects that are known by location are convenient marking elements of the section.

4. Conclusions

4.1. Conclusions on the geo-radar survey of a buried dilapidated fuel oil storage tank
Since the entire area of work is a technogenic territory with a continuously disturbed bedding of soils that are easily permeable, at the same time flooded and saturated with hydrocarbons, it was practically impossible to identify the interface between the layers. The only reliable sign for decryption was diffraction parabolas formed by the metal reinforcement of concrete structures, which, in fact, helped to outline the structure of the fuel oil storage.

4.2. Conclusions on GPR survey of the status and capacity of concrete pavement built slurry tank
When evaluating the capacity of the concrete layer of the bottom of the sludge accumulators, orientation during decoding to reinforcement over the entire area of the sludge storage allowed us to estimate the capacity of the concrete coating and get the corresponding cartogram (Fig. 9). Thus, the presence of metallic objects in the studied strata is a valuable identifying feature, and metal objects that are known by location are convenient marking elements of the section.

5. References

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