Application of electrical method to vertical HDPE film detection in landfill

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Abstract: According to the structure characteristics and site conditions of vertical HDPE film, the resistivity method is applied to the detection of vertical HDPE film. The double-arranged high-density electrical method was used to collect the data of vertical HDPE film, reverse the distribution of the profile resistivity on the vertical film, and detect the integrity of vertical HDPE film. The test was conducted combined with a landfill in Yancheng City, Jiangsu Province. And through site excavation, the effectiveness of resistivity method in vertical HDPE film detection was verified, and the shortcomings of traditional detection methods were solved. The experimental results show that: resistivity method can effectively, quickly and accurately locate shallow holes. Due to the presence of leachate, low-resistivity anomalies appear near the defects.

1. Introduction

The flexible vertical anti-seepage curtain represented by high density polyethylene (-high-density density, HDPE) film has gradually replaced the concrete continuous wall due to its good anti-seepage performance[1], acid and alkali resistance, strong anti-aging ability and many other advantages, and has been widely used in China's landfill projects. However, the vast majority of landfills are difficult to avoid vertical HDPE film defects (manufacturing process) and installation defects (geomemofilm laying and landfill operation process of sharp material perforation, stress tearing and weld cracking)[2], will greatly reduce the anti-seepage effect of vertical HDPE film, Leachate can leak through vertical HDPE membranes and enter the soil and aquatic environment where it can be hazardous to groundwater and even landfill residents." [3] Therefore, the detection of vertical HDPE film in landfill becomes very important and has important practical significance. In recent years, due to the advantages of fast and non-destructive, high spatial and temporal resolution and low environmental impact, environmental geophysical exploration methods have been paid more and more attention in the field of pollution source leakage and site pollution investigation. Resistivity method is a kind of environmental geophysical exploration method. It can solve underground problems by observing and studying the distribution law of artificially established stable electric current field. At present, the resistivity method has been applied to the pollution source leakage and site remediation in different scenarios. Since the mid-1990s, a large number of studies on the application of geophysical methods to landfill leakage detection have appeared in the scientific and technological literature. In China, Liang Yang et al. [4] conducted a study on the defects of vertical anti-seepage curtains in landfills using pumping test methods. Changxin Nai et al. [5] proposed the cable type electrical potential vulnerability during installation. Sirieix et al. [6] analyzed the resistivity characteristics of impermeable liners and pointed out that the resistivity method could be used for detecting defects in impermeable liners. Reyhaneh et al. [7] simulated defects in impermeable dams through physical experiments and successfully detected them using the resistivity method. Similarly, Lorena et al. [8] applied geoelectrical methods to successfully map the internal moisture zones of tailings dams. Although some progress has been made in the application of geophysical methods in the detection (monitoring) of landfill sites, most of the previous achievements have focused on the division of contaminated areas, migration paths, or the evaluation of pollution levels, and rarely involve the comprehensive detection of vertical anti-seepage curtains.

2. Principle and method of detection

2.1. Detection Principle

Using HDPE film for high resistance characteristics, power supply on one side of the impermeable film, theoretically the electric field is only distributed on one side of the HDPE film. However, due to the limited depth of the vertical (HDPE) film, it will not extend indefinitely underground, and A small part of the current will pass around the bottom of the film, so that the electric field

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distribution on the other side is weak, such as the power supply of A, and the potential value of A1 is almost 0. The simplified geoelectric model is shown in **Fig. 1**. If there is a leak in the impermeable film, a leakage electric field will be generated, making the potential difference between M1 and M2 on both sides of the impermeable film smaller. Therefore, the location of the leak in the impermeable film can be determined by the change of the electric field.

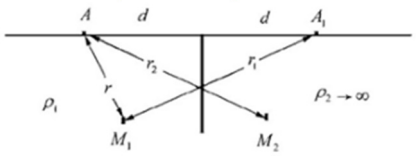

Fig. 1. Simplified diagram of impermeable membrane

The forward apparent resistivity results are shown in Figure 3. It can be seen that in the absence of holes, the apparent resistivity contour of the vertical HDPE film profile is basically in a horizontal layered state, and the apparent resistivity value of each layer is very different, and the value of apparent resistivity increases with the increase of depth. This is caused by the current seeping through the bottom of the vertical membrane.

2.2. Detection methods

Using double array CP electrical measuring device (Xiujun Guo et al., 2005), The two rows of electrodes are arranged symmetrically along both sides of the vertical HDPE film, the electrode on one side of the impermeable film is set as the power supply system, and the other side is set as the measuring system. The obtained apparent resistivity value is calculated through the measuring system, and the spatial resistivity distribution is calculated according to the measured electric field change, so as to further detect the integrity of the vertical HDPE film. Traditional methods are highly destructive, economically costly, and challenging to apply in complex geological conditions This method is characterized by its simplicity in field operations, non-destructive nature, low environmental impact, and cost-effectiveness.

3. Numerical simulation

The model was built using COMSOL Multiphysics based on the resistivity characteristics of the formation and vertical HDPE film in the study area (5.5) The software uses the finite element method to conduct three-dimensional forward modeling of the model. The model is divided into sufficiently fine tetrahedral mesh cells, each tetrahedral cell is assigned different conductivity values by the user, and the conductivity values are continuous at the grid nodes. The electric field is approximately discretized on each grid cell, and linear equations with the nodes as unknowns are established to solve the function values at the nodes, and then the function values at any point are interpolated to achieve three-dimensional forward numerical simulation. Then the inverse program was written with Matlab to invert the forward results. The inverse method adopted the damping least square method to invert the resistivity, and the accuracy and error of the location of the vulnerability were determined and evaluated.

3.1. Vertical HDPE film model

The model is established under ideal three-dimensional conditions, the size is 100 m *20 m *40 m, the surface has no topographic relief, the underground medium is uniform, the earth resistivity is 5 ohms · meters, the vertical HDPE film size is 98 m *0.01 m *30 m, the resistivity is 1*106 ohms · meters, and the hole on the vertical HDPE film profile is the cuboid size of 1 m *0 .01 m *1 m. The number of electrodes is 128, and the pole distance is 1 m. The electrodes are symmetrically distributed along both sides of the vertical HDPE film, with 64 electrodes on each side. The coordinates of the power supply electrode are (15-78m, 6m, 40m), and the measurement electrode coordinates are (15-78m, 7m, 40m). As shown in **Fig. 2**.

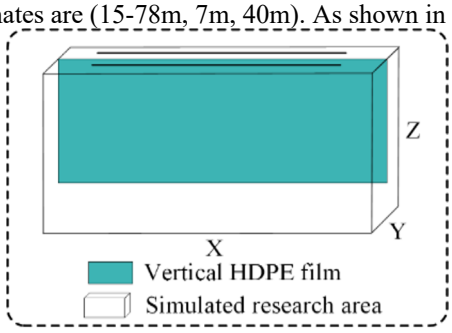

Fig. 2. Vertical HDPE film model.

The forward apparent resistivity results are shown in **Fig. 3**. It can be seen that in the absence of holes, the apparent resistivity contour of the vertical HDPE film profile is basically in a horizontal layered state, and the apparent resistivity value of each layer is very different, and the value of apparent resistivity increases with the increase of depth. This is caused by the current seeping through the bottom of the vertical membrane.

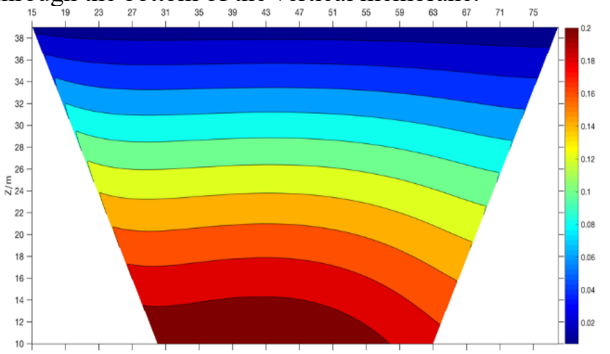

Fig. 3. The apparent resistivity diagram of the double-arranged CP electrical measuring device.

3.2. Vulnerability models of different depths

When the vertical HDPE film has a leak, its geoelectrical model is shown in **Fig. 4**, and the geoelectrical characteristics at the hole are significantly different from those at other parts of the vertical HDPE film, which provides a prerequisite for the detection of the double-arranged CP electrical measuring device. The resistivity

value of the vertical HDPE film is ρ_1, the resistivity value at the hole is ρ_1 and $\rho_1 \gg \rho_2$.

Fig. 4. Vulnerability geoelectrical model.

According to the research in the early stage of the project, there are suspected vulnerabilities in the vertical HDPE film in the area, and the horizontal position of the vulnerabilities can be determined by the peak value on the side line, and the key problem is to determine the vulnerability depth. Therefore, vulnerability models with different depths are set on the basis of vertical HDPE film so that the conductivity value is the same as that of earth conductivity to locate the location of the vulnerability. The parameters of the vulnerability model are shown in **Table 1**.

HDPE film is considered to have an infinitely high resistivity and the resistivity at the hole will be very low relative to the HDPE film. The four holes of HDPE film are simulated by resistivity and placed in different positions arbitrarily, and their positions and sizes are shown in **Fig. 5** and **Table 1**. The forward results are shown in **Fig. 6**.

Table 1. Model parameters of different vulnerability depths.

Vulnerability number	Horizontal position (m)	Vertical position (m)	Central position	Size (m*m)	Electrical conductivity S/m
1	59 ~ 60	38 ~ 39	(59.5,38.5)	1*1	0.2
2	59 ~ 60	35 ~ 36	(59.5,35.5)	1*1	0.2
3	59 ~ 60	32 ~ 33	(59.5,32.5)	1*1	0.2
4	59 ~ 60	30 ~ 31	(59.5,30.5)	1*1	0.2

COMSOL Multiphysics (5.5) software was used to conduct forward numerical simulation of the vulnerability geoelectric model, as shown in **Fig. 5**.

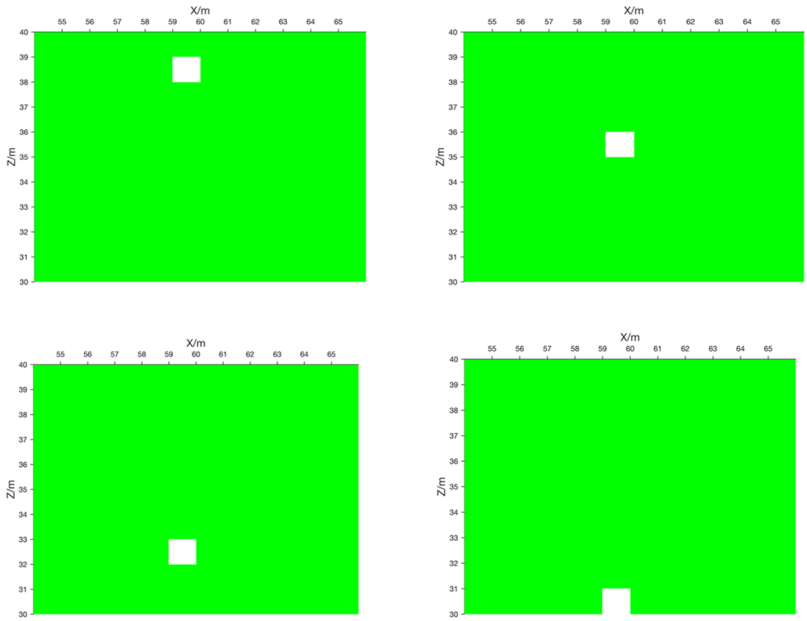

Fig. 5. Geoelectric forward modeling model with different vulnerability depths.

3.3. Result Analysis

After conducting numerical simulation, we can obtain the forward and inverse results of apparent resistance for 4 different vulnerability depths, as shown in **Fig. 6**. It can be seen from the forward chromatogram that: (1) when there is a loophole, the apparent resistivity value is larger than that without a loophole, showing a high resistance characteristic, and the forward contours show obvious changes. (2) When the vulnerability appears in the shallow part, the abnormal area can be found obviously, and the vulnerability is more consistent with the horizontal position of the model. (3) The abnormal area at the hole is larger than the size of the hole, and the morphology of the reaction changes, and the increase in the apparent resistivity value at the bottom is due to the effect of the current permeating around the hole and the current passing through the hole. (4) With the increasing of the vulnerability depth, the characteristics of the abnormal reaction zone are not obvious, and there is no high resistance anomaly, but the apparent resistivity contour near the vulnerability has obvious changes.

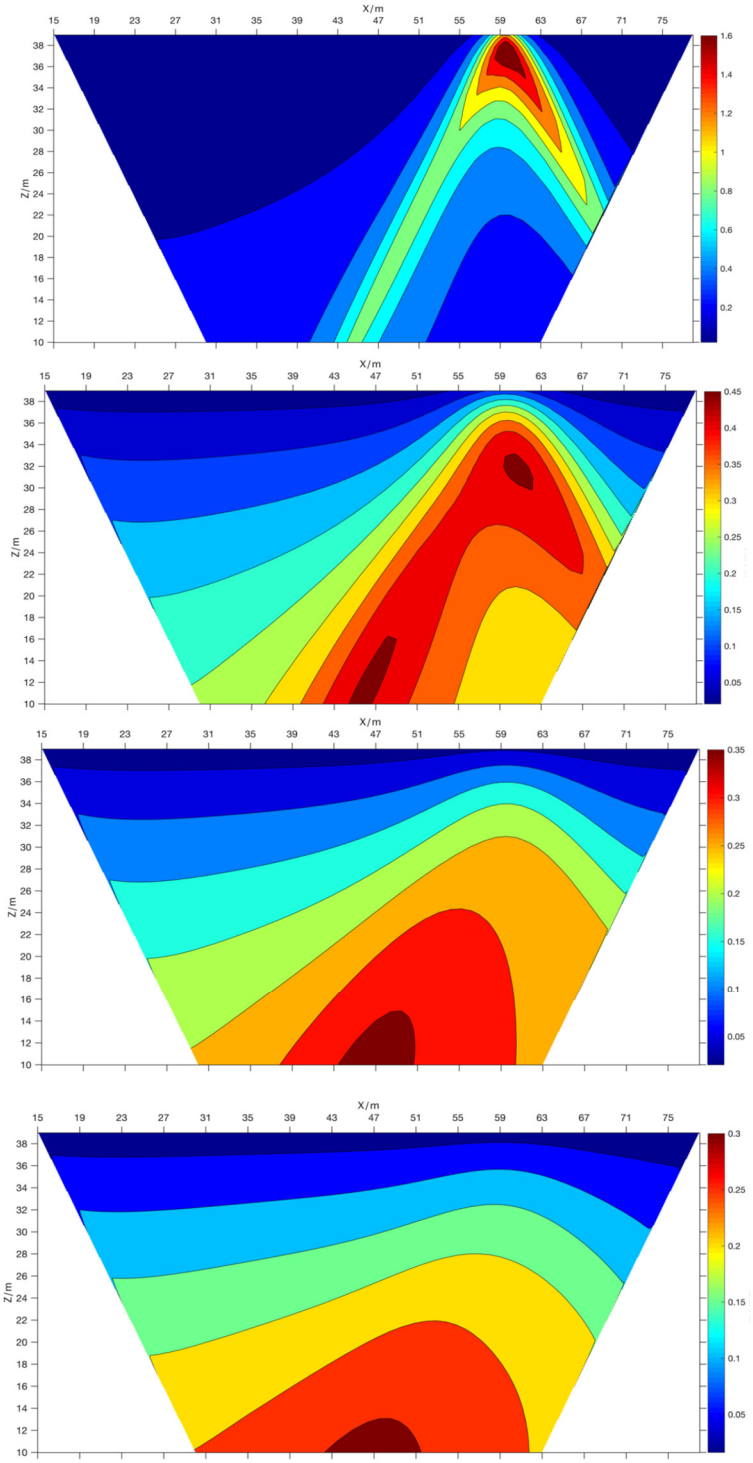

Fig. 6. Forward modeling results of different vulnerability depths.

The inversion program was written in Matlab to invert forward data of different vulnerability depths, and the results were shown in **Fig. 7**. From the inversion chromatogram, it can be seen that there are obvious anomalies near the vulnerability, and the value of electrical conductivity increases significantly, which can accurately locate the vulnerability, and the value of electrical conductivity is 0.014, which is close to the model resistivity.

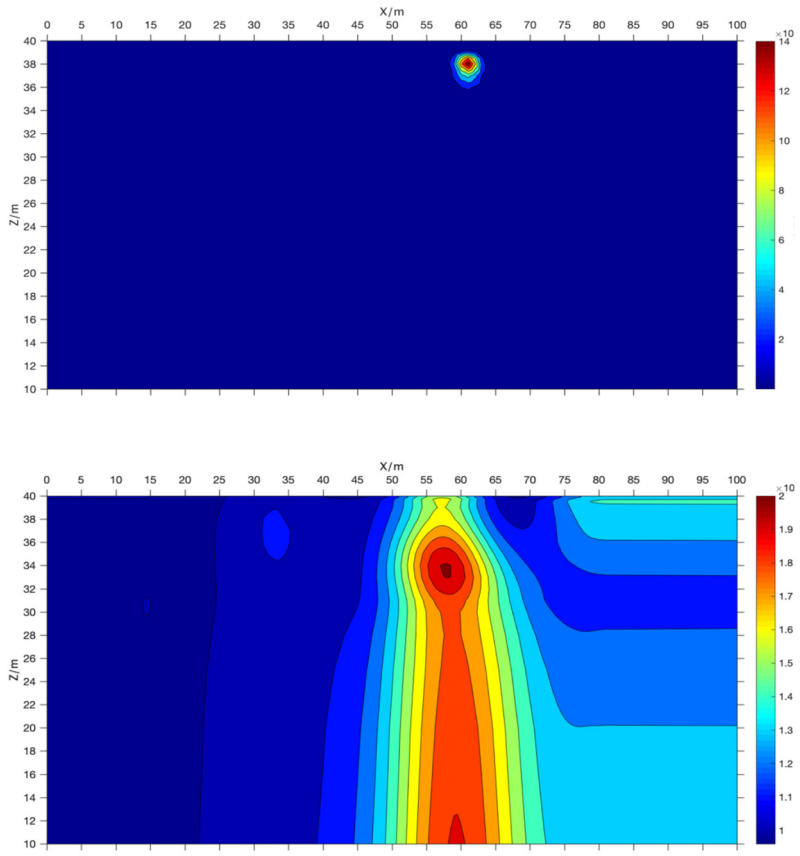

Fig. 7. Inverted results of different vulnerability depths.

4. Engineering examples

4.1. General situation of landfill site

The landfill site is located in the southeast of the first phase of the southern Zone of Lingang Industrial Zone, a Marine economic Comprehensive Development Zone of Jiangsu Province. The vertical anti-seepage wall is arranged in the ring warehouse, and a two-layer anti-seepage system is arranged around the landfill site. The inner vertical anti-seepage system adopts the cement mixing pile technology, and on the outside, the process of bentonite wall and HPDE membrane cureproof wall is adopted, which is located about 3.5m outside the axis of the inner vertical cureproof wall.

4.2. Working Methods

The outer vertical HDPE film in the eastern region was tested. There were 64 electrodes on both sides of the HDPE film, the electrode distance was 1m and the HDPE film was 0.5m. A total of 1920m2 area was measured by the apparent resistivity profile method of the double-arranged CP electrical measuring device.

4.3. General situation of landfill site

The potential data measured in the field were pre-processed, and the apparent resistivity profile was formed according to the double-arranged CP electrical measuring device (Xiujun Guo et al., 2005), as shown in **Fig.8**. It can be seen that there are obvious abnormal areas, and there is a hole in the vertical HDPE film, whose apparent resistivity value is 0.8. Inversion of the field apparent resistivity data can obtain the resistivity distribution of the vertical HDPE film profile and locate the hole, which is located at (51.5,34) meters.

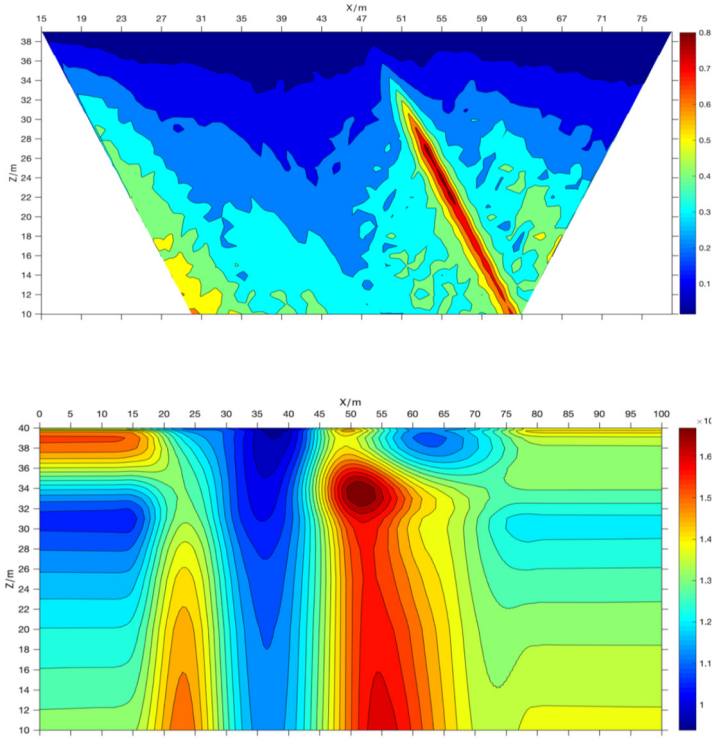

Fig. 8. The measured apparent resistivity profile and inversion results of double permutation CP.

5. Conclusion

(1) Low impedance anomalies are closely related to the presence of leachate. Once an HDPE membrane develops a defect, the originally isolated leachate can infiltrate, forming localized low impedance anomalies. The location and shape of membrane defects determine the leakage path, which in turn manifests as different low impedance distributions in measurements. On the basis of investigating the underground resistivity characteristics of the landfill site, the paper adopts a double-aligned CP electrical measuring device through forward simulation, and detects the vertical HDPE film hole location by the resistivity method, which is consistent with the later excavation verification.

(2) In order to be simple and effective, the resistance value of vertical HDPE film is set to be particularly large, and the prior information model is added for inversion. The boundary problem is not considered, and the impact of the boundary problem on the numerical simulation accuracy should be further studied in the future.

(3) The resistivity method can effectively detect the scale and distribution of vertical HDPE film holes, which is an economical and effective detection method.

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