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Guan Shao-peng
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Guan Shao-peng
Shandong Institute of Business and Technology, Yantai 264005, China, konexgsp@163.com
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Abstract

The grounding resistance of power electrode plays a decisive role on the source current in landfill leakage detection using electrical method. A model of grounding resistance for cylindrical electrode was set up in this paper. The corresponding resistance expression was derived, and the main influence factors were also analyzed. The results show that: 1) the electrode grounding resistance is mainly determined by the resistivity of surrounding soil; 2) as the buried depth and the diameter increase, the electrode grounding resistance reduces. When the buried depth exceeds 40cm, the electrode grounding resistance is slightly influenced by the buried depth. Therefore, the buried depth and radius of power electrode should be as large as possible in practice. In addition, the soil around the power electrode should be watered to reduce the grounding resistance. Experiments validate the conclusions.

Keywords: *Landfill, Leakage Detection, Electrical Method, Grounding Resistance*

1. Introduction

Numerous solid wastes are generated every year in China. The most common method of disposal of solid wastes is in landfills. To prevent contamination, geomembrane liner systems are needed in the landfills. Those liners, placed beneath the landfill and possessing excellent impermeable performance, are designed to form an impermeable barrier to prevent the migration of contaminant liquids. However, incorrect welding and cross operation often lead to leaks in the liners, causing loss of physical integrity during installation. It is reported that there was an average of 15.31 leaks per hectare for 25 landfill liners in Italy in 1995, an average of 22.5 leaks per hectare for surveyed impoundments in America in 1993, 2.03 leaks per hectare for bare geomembrane liners at eleven sites in Canada and France in 1999 [1-3]. Geomembrane liners are effective only when they retain physical integrity. Therefore, integrity survey of the geomembrane liners is important after installation. At present, many detection methods have been put forward. But the electrical leak location method was the only one method that can not only detect but also locate the leaks without damage to liners [4-9]. This method locates leaks by measuring the potential distribution patterns in the medium above the liner based on the fact that the geomembrane liner material is high resistance. When no leaks are present, a voltage impressed across the liner produces a relatively uniform voltage potential distribution in the material above the liner. A leak in the geomembrane liner provides a conductive path for current flow, causing a potential anomaly in the vicinity of the leak. Therefore, leaks can be located by the potential distribution patterns in the material above or under the liner [10-14]. The potential anomaly is proportionate to the current flowing through the leak. The more the current is, the more obvious the potential anomaly is, then the more easily the leaks are detected. Under certain supply voltage, the grounding resistance of power electrode plays a decisive role on the current size. The smaller the power electrode grounding resistance is, the more the source current is [15]. We studied the grounding resistance of cylindrical electrode. The expression was deduced. Experiments were also conducted to validate the conclusions.

2. Theory

In practice, the cylindrical electrodes are often selected for convenience of operation. The model is set up shown in Figure 2. The buried depth is supposed to be l_0, and the radius of cylindrical electrode is r_1.

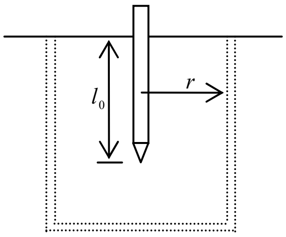

Figure 1. Model of cylindrical electrode

Compared with the soil, the resistivity of cylindrical electrode made of stainless steel is very small. It can be regarded as an equipotential body. Taking the center line of the cylindrical electrode as axis, the soil is divided into a series of cylindrical layers from the electrode surface to infinity. The thickness of each layer is *dr* (*dr*<< *r*). Then, the grounding resistance of the electrode is the sum of resistances of the series cylinder layers.

For any cylindrical layer, the surface area can be written as,

$$S = \pi r^2 + 2\pi r(r + l_0 - r_1) \tag{1}$$

Where, *r* is the distance from the cylindrical layer to the electrode axis. Therefore, the resistance of the cylindrical layer of soil is given by

$$\mathrm{d}R = \rho \frac{\mathrm{d}r}{\pi r^2 + 2\pi r(r + l_0 - r_1)} \tag{2}$$

The grounding resistance of cylindrical electrode is the integration of Equation (2) by *r*,

$$R = \int_{r_1}^{\infty} \mathrm{d}R = \int_{r_1}^{\infty} \frac{\rho \mathrm{d}r}{\pi r^2 + 2\pi r\left(r + l_0 - r_1\right)} = \frac{\rho}{2\pi\left(l_0 - r_1\right)} \ln \frac{r_1 + 2l_0}{3r_1} \tag{3}$$

It can be seen that the grounding resistance of cylindrical electrode is proportional to soil resistivity (ρ), and relative with the electrode radius (r_1) and the buried depth (l_0).

Figure 2 shows the grounding resistances computed for various electrode radiuses. The buried depth is 0.5m, and the soil resistivity is 100Ω.m.

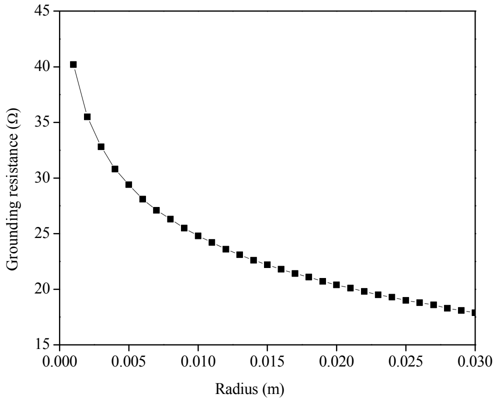

Figure 2. Grounding resistance computed for various electrode radiuses

Grounding resistances are illustrated for different buried depths in Figure 3. The data is computed with an electrode radius of 10mm and a soil resistivity of 100Ω.m.

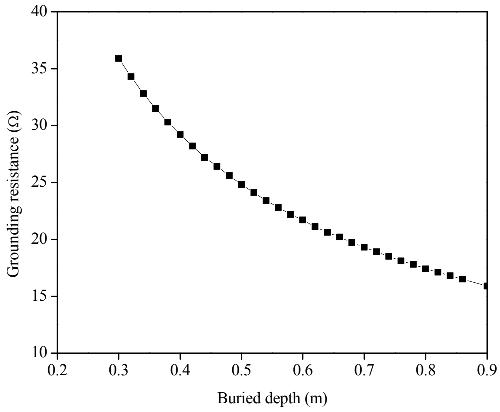

Figure 3. Grounding resistance as a function of the buried depth

The effect of the distance *r* on the grounding resistance is calculated. The buried depth is 0.5m with a soil resistivity of 100Ω.m. the results are displayed in Figure 4.

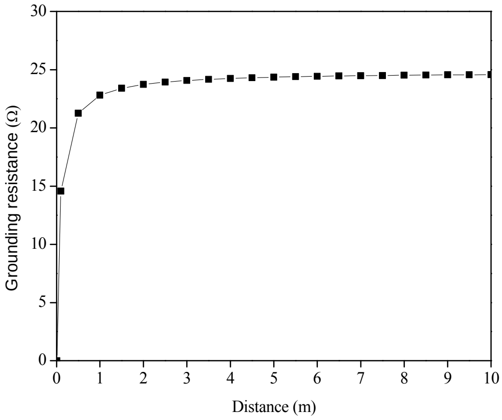

Figure 4. Grounding resistance as a function of distance

Figure 4 shows that the grounding resistance of cylindrical electrode is mainly determined by the surrounding soil. As the distance increases, the grounding resistance quickly increases and then keeps steady. The grounding resistance to a distance of 1m account for 83% of the total resistance. Therefore, the grounding resistance can be significantly reduced by watering the surrounding soil when the electrode is placed in dry soil. It should be noted that the above conclusion is based on the fact that the electrode is in a good contact with surrounding soil. In fact, the soil is generally granular, which lead to a bad contact between the electrode and the soil. In addition, the soil is not completely homogeneous. These factors make the actual resistance is much greater than the theoretical value.

3. Experiments

3.1. Effect of buried depth

Experiments were conducted in a square with flat and homogeneous soil. Two stainless steel cylinders with a diameter of 18mm and a length of 2m were selected as the experimental electrodes. The first electrode was buried in soil 1m deep. The second electrode was buried 10m away from the first one. Keeping the buried depth of the first electrode unchanged, the resistances between the two electrodes were measured as a function of the buried depth of the second electrode with different voltages. The results were illustrated in Table 1.

Table 1. Experimental results of grounding resistance as a function of buried depth **(**kΩ)

Voltage/V	**Buried depth/cm**								
	5	10	15	20	30	40	50	100	150
80	1.251	1.143	0.721	0.667	0.64	0.625	0.61	0.479	0.411
200	1.224	0.843	0.683	0.633	0.613	0.581	0.575	0.455	0.383
300	1.228	0.845	0.682	0.633	0.612	0.581	0.573	0.448	0.383

As shown in Table 1, the electrode grounding resistance decreases with increasing of electrode buried depth. When the buried depth is larger than 40cm, the decrease speed of the grounding resistance slows down. Therefore, in application, the power electrodes are usually adopted with a length of 50cm and buried 40cm deep.

3.2. Effect of radius

The experimental site was the same as above. The same two electrodes were adopted. The first electrode was buried with a depth of 1m. The second electrode was buried with the same depth 10m away from the first one. Keeping the buried depth of the two electrodes unchanged, the resistances between the two electrodes as the function of the second electrode radius were measured shown in Table 2.

Table 2. Experimental grounding resistance as the function of the electrode radius (kΩ)

Voltage/V	**Radius/mm**					
	5	**10**	**15**	**20**	**30**	**40**
80	1.251	1.143	0.721	0.667	0.64	0.625
200	1.224	0.843	0.683	0.633	0.613	0.581
300	1.228	0.845	0.682	0.633	0.612	0.581

Table 2 illustrates that the grounding resistance decreases as the electrode radius increases. Therefore, the electrode radius in practice should be as large as possible.

4. Conclusions

The electrode grounding resistance is mainly determined by the surrounding soil. To water the soil around the electrode can significantly reduce the grounding resistance. In addition, the resistance also affected by the radius and buried depth. The electrode grounding resistance decreases with increasing of electrode buried depth. When the buried depth is larger than 40cm, the decrease speed of the grounding resistance slows down. With the increase of electrode radius, the grounding resistance decreases. In practice, the electrode with larger diameter is often selected.

5. Acknowledgement

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