An Attempt to Estimate the Level of Non-confind Groundwater by Earthing Resistance (I) - Outline of Theory -

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1. Introduction

In the Musashino district of the Kanto plain, some loam layers for several meters with good permeability cover the Musashino gravel layer. The groundwater under no pressure here uses the Musashino gravel layer as the main aquifer. However, the seasonal recharge may raise the water level to the upper loam layer. The impermeable layer, which has a clay-rich lens shape, is often present in the loam layer (Kakuda, 2017). As the perchied water level rises to near the surface of the earth, flood damage is brought about occasionally (for example, Tokyo Metropolitan Geological Survey Association, 2000). Therefore, observation of such groundwater level fluctuation at many points is required to prepare for flood damage. Ohshima *et al*. (2015) examined the stability of these earthing resistances, in order to use the housing foundation as the earthing electrode to ensure safety for the electrical equipment, using a small model foundation of about 2 m ×2 m or the building foundation of a real scale housing. According to this, it was shown that there is a seasonal fluctuation in earthing resistance of about 200% in the small model or about 20% to 30% in the real scale. It is thought that this fluctuation is caused by the characteristic accompanying the temperature change. On the other hand, the observations of groundwater level at the wells around Inokashira pond, from the beginning of December 1988 until March 2001, showed that the peak-to-peak annual change of 2 m to 3 m (Kokubu, 2005). These variation in the groundwater level makes to change the earthing resistivity, and it becomes a factor of changing the earthing resistance of the electrode (Ryoki, 2019). In this memoir, the conseption is introduced, and then, it has been proposed that a method for estimating the level, based on the contribution of the variation of the groundwater level to the earthing resistance.

2. Theory

Consider the point current I flowing from the origin O to the ground of the semi-infinite medium with the resistivity ρ, the potential V_r, that is created on the surface of the distance r, is $V_r = \rho I / 2\pi r$. When the hemispherical metal electrode of the radius a, which instead of the point current source, is grounded, the potential in the metal becomes equal to the potential $V_a = \rho I / 2\pi a$ on the surface. Therefore, R, as the resistance of the origin O (*eq*. the resistance value of the hemispherical metal electrode) viewed from infinity, is expressed as follows; $R = V_a / I = \rho / 2\pi a$. This is the earthing resistance of the hemispherical metal electrode.

Next, let us consider the ground potential when the earth is regarded as a horizontal two-layers structure. According to the mirror image method (Figure 1) shown by Hagiwara (1951), the potential $V_{0(r,\ z=0)}$ on the ground surface, z=0, at the distance r made by the point current source is as follows; $V_{0(r,\ z=0)} = \rho_1 I(1/r + 2\Sigma^{\infty}_{k=1}(Q^k/(r^2+(2kd)^2)^{1/2}))/2\pi$. Where Q is the reflection coefficient with respect to the current density; $Q = (\rho_2 - \rho_1)/(\rho_2 + \rho_1)$. ρ_1 and ρ_2 are the resistivities of the first layer and the second layer, respectively. d is the layer thickness of the first layer. Now, consider R_a, the earthing resistance of the earth electrode on the two-layer structure, as in the case of Wenner's method which is a vertical electrical prospecting, letting $r=a$; $R_a = V_a / I = \rho_1(1/a + 2\Sigma^{\infty}_{k=1}(Q^k/(a^2+(2kd)^2)^{1/2}))/2\pi$. This is able to call the equivalent earthing resistance. Consider the ratio of R_a to the earthing resistance R_1 which is in the semi-infinite medium consisting only of the first layer of resistivity ρ_1; $R_a/R_1 = 1 + 2\Sigma^{\infty}_{k=1}(Q^k/(1+4k^2(d/a)^2)^{1/2})$. This is able to call the apparent resistivity with respect to the equivalent earthing resistance.

Fig. 2 shows the relationship between d/a and R_a/R_1, here, d: thickness of the first layer, a: radius of the hemispherical conductive electrode. Shown in Fig. 2, it is able to understand that the equivalent earthing resistance takes a change when the groundwater level varies. Therefore, it is able to expect that variations in groundwater level is sensed by monitoring fluctuation of earthing resistance.

3. Future plans

In order to verify the method introduced here, the observation well will be drilled, and the fluctuation of the groundwater level *etc.* will be measured there. Then, the earthing resistance of the earth electrode for safety of electrical equipment will be continuously measured. The planned observations are (1) the groundwater level, (2) also the temperature, (3) also the electrical conductivity, (4) the apparent resistivity of the earth, and (5) the earthing resistance. Preliminary measurement results will be shown at the JpGU meeting.

Keywords: electrical equipment, Musashino district, loam layers, perchied water, flood damage, equivalent earthing resistance

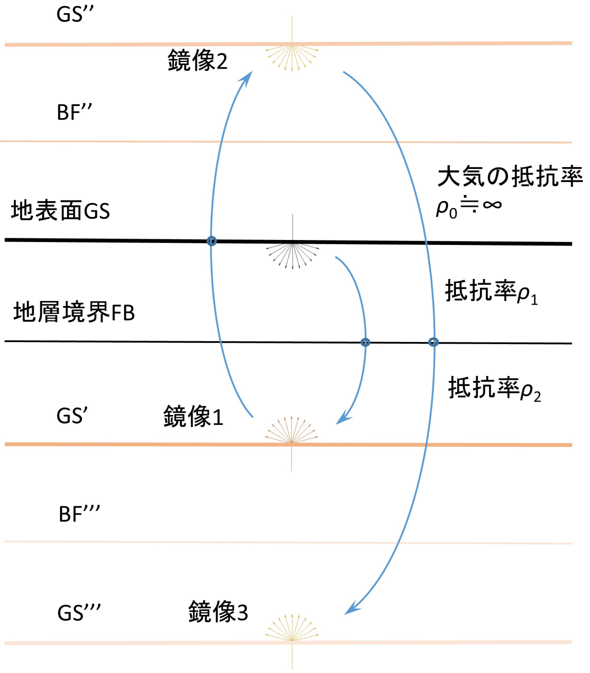

図1　鏡像法の概念図 (領木, 2019).
Fig. 1. Conceptual diagram of the mirror imaging method (Ryoki, 2019).

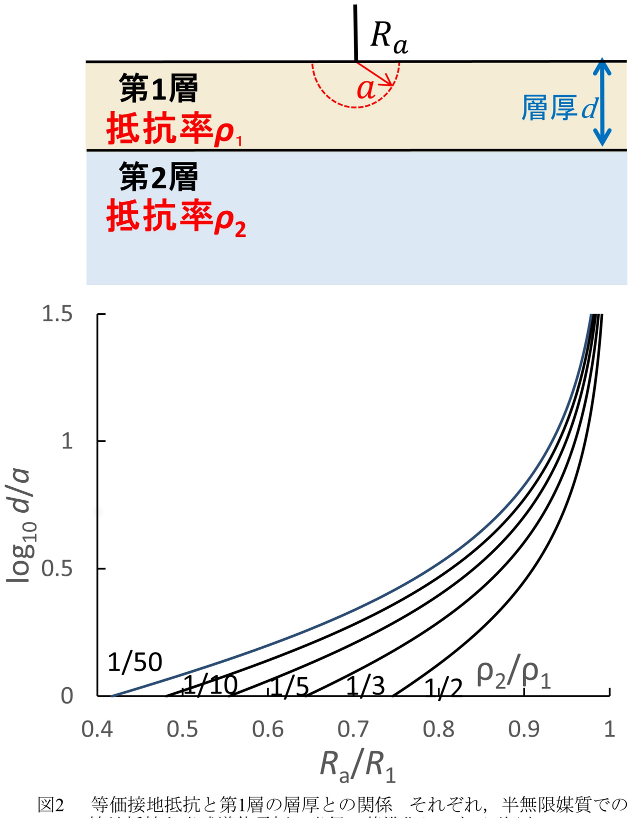

図2　等価接地抵抗と第1層の層厚との関係　それぞれ，半無限媒質での接地抵抗と半球導体電極の半径で基準化してある (領木, 2019).
Fig. 2. Relationship between the equivalent earthing resistance and the 1st layer thickness. Parameters are nor-malized by the earthing resistance in the semi infinite medium and the radius of the hemi-spherical conductor electrode, respectively (Ryoki, 2019).