Electrical survey for continuous evaluation of filled structure for ancient manmade embankment

Yoshinori Iwasaki

Geo Research Institute, Kokumin-Kaikan 6th Fl , 2-1-2,Ohtemae, Chuo-ku, Osaka City, 540-0008, Japan

ABSTRACT

This paper describes the leading edge technology of combination of geophysics of electric survey and geotechnical engineering to clarify the inside of manmade embankment of ancient dam. Ancient dam, which was constructed several hundred years ago, is difficult to estimate the inside structure of clayey or sandy soils without trench excavation. The proposed method intends to clarify the zoning of the inside section of the embankment based upon the electrical survey and unified cone penetration tests.

Keywords: electric survey, cone penetrating test, levee structure, soil classification

1 INTRODUCTION

There are several ancient dams in Japan, which were constructed as early as in 7th- 8th centuries. One of such dam is Manno-Dam in Shikoku as shown in Figure 1.

The Mannoh-dam was originally constructed in 701-704 AD. The dam had been damaged several times by floods and earthquakes and rebuilt several times. At present, the dam height is 32m with the length of the embankment is 155.8m.

International Commission on Irrigation and Drainage, ICID, nominated the Manno-Dam as Heritage Irrigation Structure in 2016.

These ancient dams which were made of earth fill are difficult to estimate the dam structure. Even though several borings were carried out, the results show only the information of these points of borings.

Among several geophysical surveys, electric method is considered as to provide "potential capability to display continuous sections of different soils of clay or sand. Since the measured values of electric resistance is considered to correlate with soil characteristics to electric resistance. Generally, clayey soil shows lower resistance than sand and gravel soils.

Figure 1
The Manno-Dam
Ehime-Pref., Japan
Height 32m
Length 155.8m

2 ELECTRIC SURVEY AT RIVER BANK

The Electric survey method "Ohm-mapper (Products of GEOMETRICS, USA)" provides rather easy survey without fixed electric nodes into ground, which only uses electrodes above the ground surface.

River embankments are the same situations as the difficult situations to study the geotechnical sections along the river.

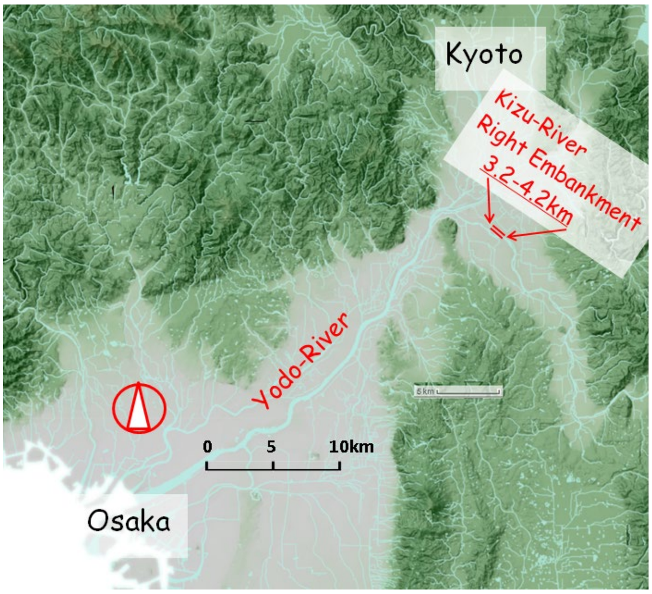

Figure 2 Electric survey site at 3.2-4.2km Kizu-River

Among several sites of the electric survey made to clarify the application of electric survey to river bank, a case study was carried out at the Kizu-River from 3.4 to 4.2 km, which is located between Kyoto and Osaka as shown in Figure 2.

Figure 3 Ohm-mapper field work

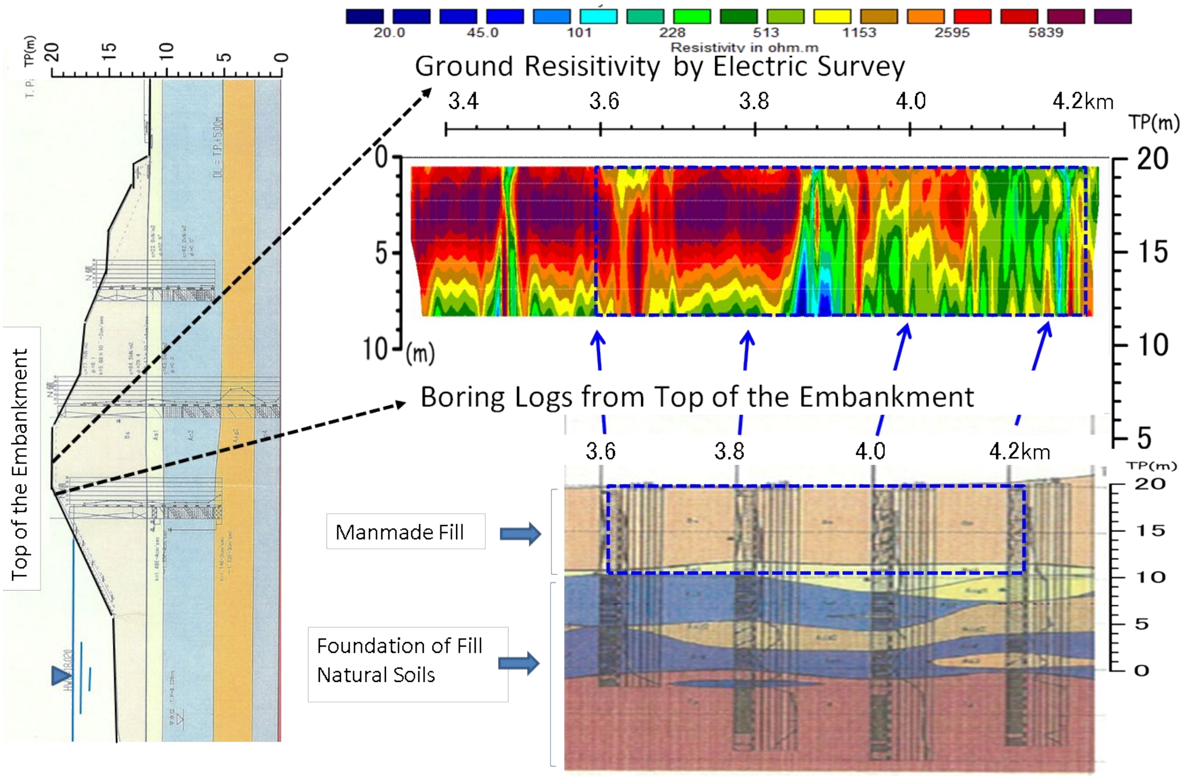

Figure 3 Comparisons of Borings and Electric Survey

Ohm Mapper Survey is shown in Figure 2, where a man is walking with pulling a cable with electric nodes.

Borings have been carried out at sections of every 200m along river banks in Japan to geotechnical characterization and Figure 3 shows the comparisons between borings and electric surveys. The results of the boring for embankment section of the top of the embankment of +20m to 18m shows only ”sandy manmade fill.” The results of the electric survey shows rather clear boundary around 3.9km, a boundary between the very high resistivity(in red) and low resistivity(green to blue). It is already known that sand and gravel show high resistivity and clayey soils show low resistivity as the general tendencies. However, the resistance depends also the electric conductivity of the water in the ground, the relationship between the absolute value of the resistance and soil type is different for each site. To obtain the relationship between electric resistance and soil type, a simple cone field test was introduced in this study.

3 UNIFIED FIELD CONE TEST

In geotechnical engineering, field equipment of “three component penetration test” has been developed to obtain soil characteristics. One of such device is the “Unified field cone” as show in Fig.4. Conventional three component cone test measures 1.penetrating cone resistance, 2.frictional resistance, and 3. Porewater pressure. In addition to the above mentioned values, the unified cone provides logging results for soil density and water content by gamma ray and thermal neutron as well as electric logging. Based upon the three component cone test, a soil classification index Ic was proposed (Jefferies M.G. and Davis, 1993).

$$I_c = \{(3.47\text{-}\log Q_t)^2 + (\log F_r + 1.22)^2\}^{0.5}$$

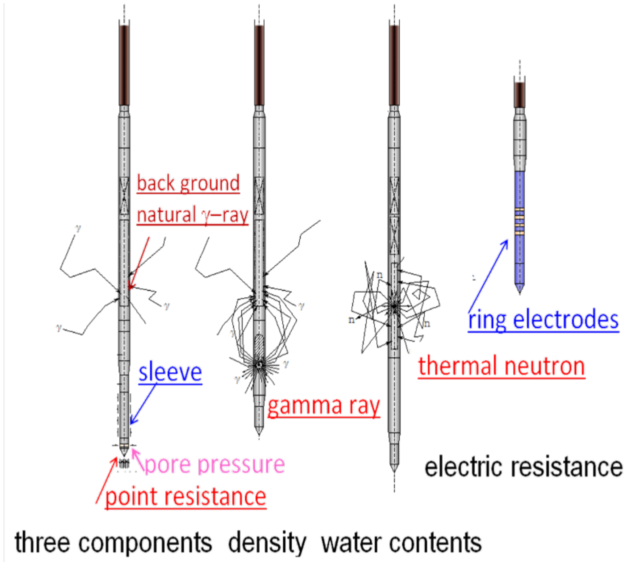

Figure 4 Unified Field Cone Tester

The soil classification Index is a function of Qt and Fr that are normalized values of the penetrating pressure qt and the frictional resistance fs divided by overburden pressure of σ_{vo}, σ'_{vo} respectively. Table -1 shows the relationship between the Classification Index and classified soils.
Fig.2 shows the results of soil classification as soil column that the soils are classified into gravel, sand, intermediate, and clayey soils.

Table-1 Ic and Soil Classification

Ic	Soil Classification
～1.31	gravel
1.31～2.05	sand – silty sand
2.05～2.60	silty sand – sandy silt
2.60～2.95	sandy silt – silty clay
2.95～3.60	silty clay – clay
3.60～	peat

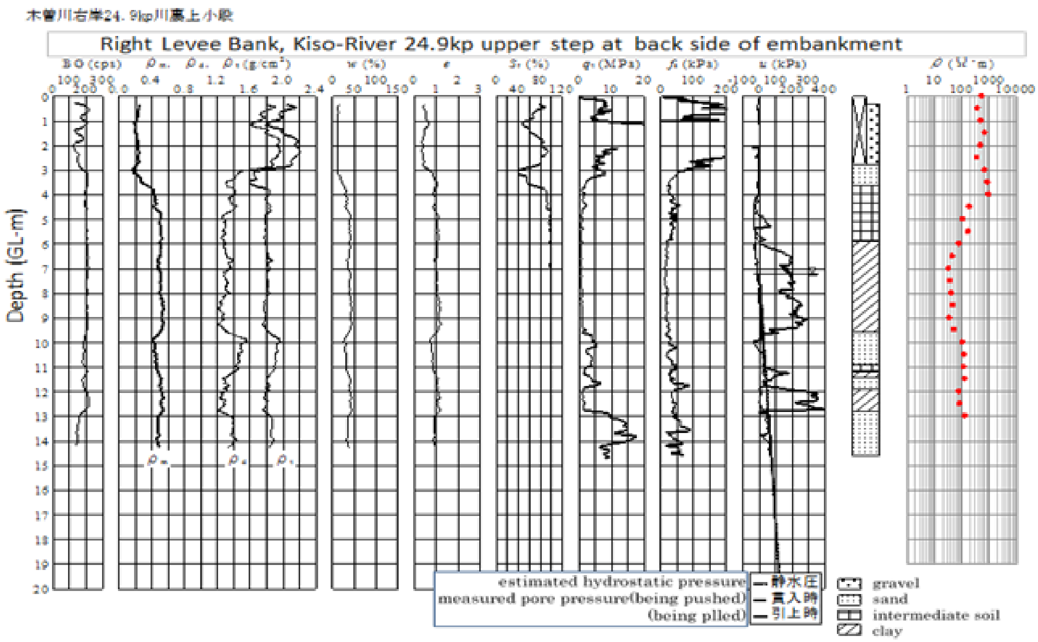

Figure 5

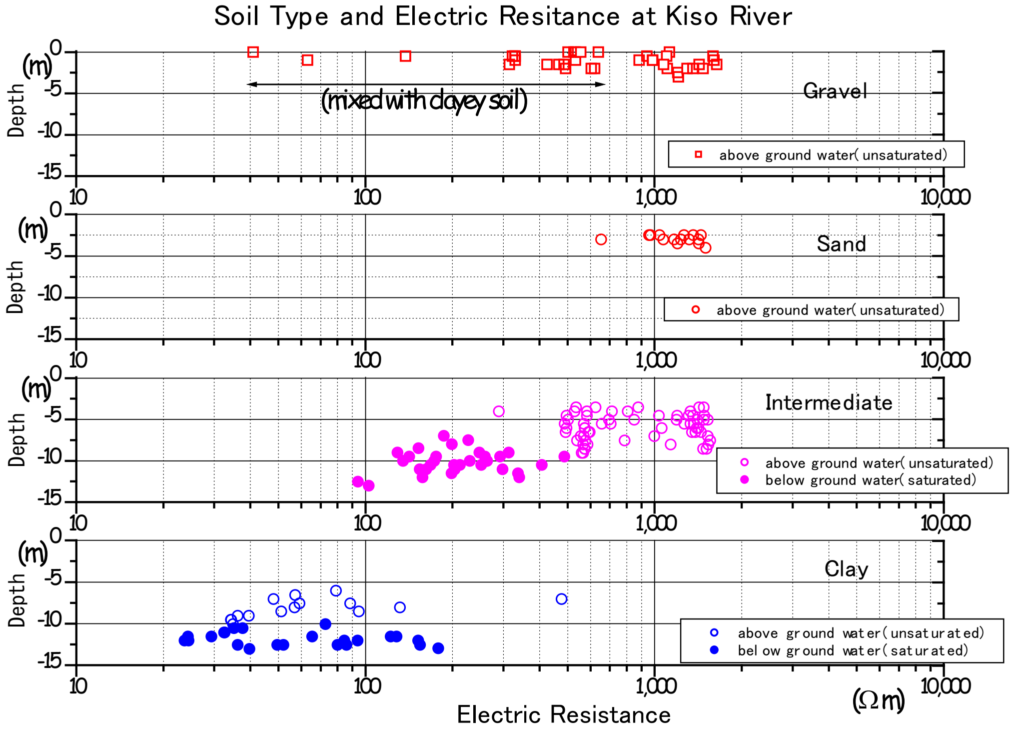

Figure 6 Soil types and Electric resistance

4 ELECTRIC RESISTIVITY OF SOILS

Fig.5 shows the range of the electric resistivity for the measured levee of Kiso River. Gravel and sandy soils show high resistivity with some exception of low resistivity that contains some clay. On the other hand, clayey soil shows low resistivity of less than 200 Ohm m.

Table 2 Electric resistance of soil types

Soils	Electric Resistivity (Ohm m)
Gravel and Sand	1000<
Intermediate Soils	100< <2000
Clay Soils	<200

Intermediate soil shows rather wide range from 100 to 2000 Ohm m, which covers wide ranges of clay and sand/ gravel ones. Laboratory soil tests were carried out to study the relationship between the degree of saturation and the electric resistivity. Fig.7 shows the results of the effects of saturation of soils upon electric resistivity.
The increase of the degree of saturation for intermediate soils gives low level of the resistivity as clayey soil.

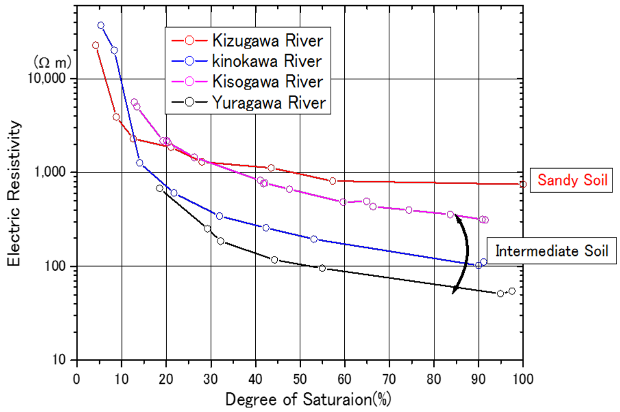

Figure 7 Effects of saturation upon electric resistivity of soils

4 CONCLUSIONS

The ancient dams were usually constructed using various types of soils. Usually boring surveys are applied to study the soils of the dam. However, it is very difficult to obtain continuous soil profiles. The electric survey provides an excellent geophysical method to show continuous image of the section of the embankment of river and ancient earth dams.

The electric survey may be introduced as the preliminary method to study the general continuous profile. Based upon the electric image of the embankment, boring or the unified cone test is used to identify each grouped sections and to give geotechnical characteristics.

Reference

Mamoru Mimura(1), Yoshinori Iwasaki(2), Koichi Nakagawa(3), Akira Jomori(4), and Mitsugu Yoshimura(5), Teruyuki Fujiwara(2) , and Masanori Uno(1) "A case study of soil type identification for levee structure by electric survey with unified cone field test", Proceedings of the 12th SEGJ International Symposium, 2015