Examination of flowing groundwater condition on riverbank bed using One-meter Depth Temperature and Multipoint Temperature Logging

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Abstract Various types of soil disaster related with groundwater behaviour. Especially, flowing groundwater flows in very local area causes destabilization of the soil structure. It is very important for clarification of mechanism of the soil disasters. However, exploration of flowing groundwater in local area is very difficult because of heterogeneity of soil quality and groundwater condition. This paper has provided principle and measurement results of two types of exploring method of flowing groundwater. One-meter Depth Temperature method is developed to get information of flowing groundwater route reflected by the ground surface. One-meter Depth Temperature is simple, inexpensive and stable method to detect the local flowing groundwater. We can get information of existence of flowing groundwater by measuring one-meter depth soil temperature, simply. Multipoint Temperature Logging method is also developed. We can get information of vertical location of layers with flowing groundwater. Boring hole was used in Multipoint Temperature Logging method. Measurement of vertical temperature distribution of temperature decreasing process indicates the location of the layers with flowing groundwater. Results of these two methods indicated the three dimensional location of existence of the flowing groundwater in detail.
Keywords. flowing groundwater , One-meter Depth Temperature method , Multipoint Temperature Logging method

1. Introduction

Many studies towards establishment of the safety diagnosis method of a riverbank have been carried out. According to the fundamental guideline of riverbank, in addition to shape consideration, it is necessary to exam in consideration of non-homogeneity of riverbank and bed for designing of the riverbank. Since the riverbank leakage causes less than the high-water level, understanding of destruction process based on the heterogeneity of the soil and establishment of the efficient maintenance management technique are urgent problem. It is very difficult to clarify the existence condition of the groundwater in heterogeneity field. TAKEUCHI[1)] developed a flowing groundwater exploration method by temperature index in order to grasp a groundwater based on heterogeneity, and this exploration method has mainly solved groundwater problem of the landslide. We applied this flowing groundwater exploration method as exploration method of the leakage of riverbank base in WATARASE River, and have verified validity. In this study, Boring investigation and Multipoint Temperature Logging were performed at the point where we could strong result of flowing groundwater by One-meter Depth Temperature method. The compatibility of results of investigations and characteristics of flowing groundwater were examined.

2. Materials and methods

2.1. One-meter Depth Temperature method

One-meter Depth Temperature method is an exploration method which detects existence of flowing groundwater the temperature anomaly of the soil temperature in 1 m depth which is not exist daily variation of soil temperature. Insert the temperature sensor into 1m deep hole. Then, measure the soil temperature in 1m depth when the sensor was adjusted with surrounding soil temperature. (Fig. 1. One-meter Depth Temperature method, Fig. 2. Process

of operation) Investigation method called flowing groundwater described in this study don't have sensitivity with accumulated groundwater because of averaging with surrounding soil temperature completely. According to this characteristic, the flowing groundwater methods can detect only flowing groundwater without accumulating groundwater. Validity of the flowing groundwater has been verified by many results of field measurements. And the flowing groundwater method has been already applied to business work. It has been mainly used for the measurement against the landslide. In case of the landslide investigation, groundwater flows to downslope direction. However, in case of the riverbank bed leakage investigation, flow direction can be alternative. Then, usual temperature in 1m depth is explained in the following. In the summer, usual temperature in 1m depth is higher than groundwater temperature. During this reason, soil temperature in 1m depth with flowing groundwater is lower than the usual. (Fig. 3)In winter, measured soil temperature is higher than the usual, conversely. Moreover, although usual temperature in 1m Depth does not receive a daily variation by solar radiation, it has an annual change. (Fig. 4) As shown in Fig. 4, the period which there isn't useful difference between usual temperature in 1m depth and flowing groundwater temperature exists twice a year. Generally One-meter Depth Temperature method is not carried out during the period.

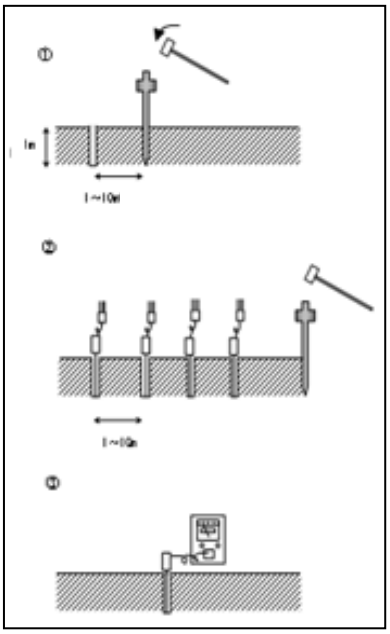

Fig. 1. The instrument of One-meter Depth Temperature method Fig. 2. Process of operation

2.2. Multipoint Temperature Logging method

The technique and theory of the Multipoint Temperature Logging method are as follows. By pouring warm water into a boring hole, the temperature in a hole can be warmed almost uniformly and the temperature recovery situation in each depth is measured with time. A difference appears in the place where the flowing groundwater layer exists. Thereby, the information about the existence depth of the flowing groundwater layer and its thickness can be acquired. (Fig. 5, Fig. 6) The result of the Multipoint Temperature Logging method is expressed using "the graph of temperature and depth." The total number of the flowing groundwater layers and the information on existence depth are acquired by comparing the curve of the temperature of a natural state with the raised curve of temperature, and reading the quick part of temperature recovery. Moreover, even if it uses "the graph of a temperature restoration rate and depth", the information on the fluid bed can be acquired. For judging a very late flowing groundwater, the diffusivity of heat of water serves as a judging standard. In this case, the temperature restoration rate at the time of 30-minute measurement will be about 60%. Therefor, region with 60% or more of the restoration rate indicates existence of the flowing groundwater layer. Moreover, about the place shallower than the groundwater level in well, the temperature restoration rate has judged 80% or more to be the flowing groundwater layer. The temperature restoration rate by the following equation.

$$R = \frac{(\text{initial hot water temperature}) - (\text{temperature in anytime})}{(\text{initial hot water temperature} - \text{normal condion})} \times 100(\%)$$

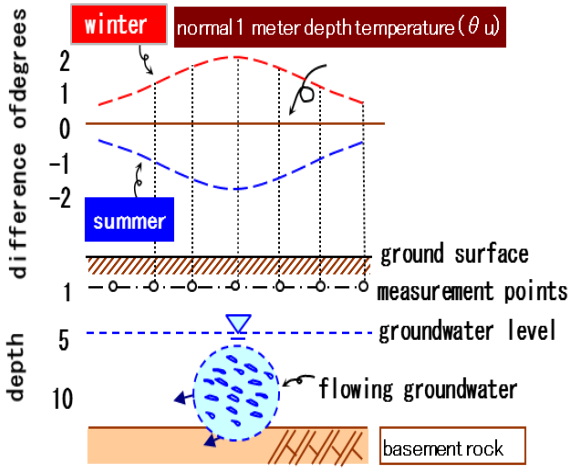

Fig. 3. The outline of usual temperature of 1m depth

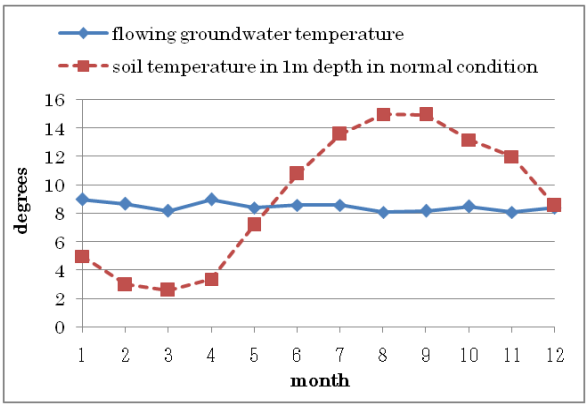

Fig. 4. The annual change of flow groundwater and usual temperature of 1m depth

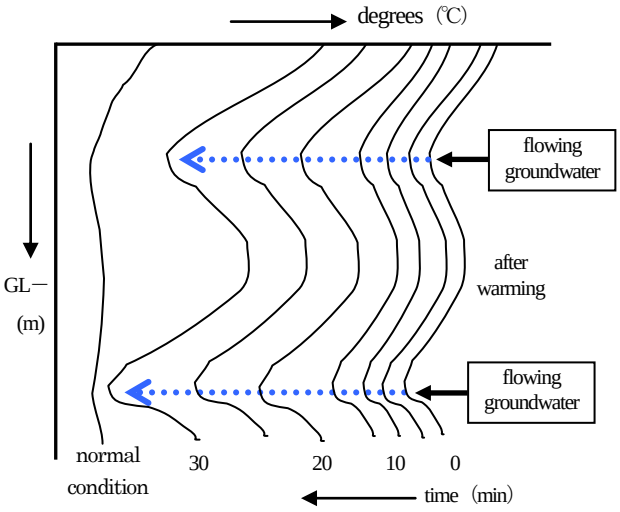

Fig. 5. Theory of the Multipoint Temperature Logging method

Fig. 6. The instrument of the Multipoint Temperature Logging method

3. Field measurement

3.1. Measurement site

Field measurement was performed in the right bank of the WATARASE River in FUKUTOMI-cho, ASHIKAGA-shi, TOCHIGI- prefecture. In the result of the riverbank detailed check carried out before, this is the place where it was apprehensive about the safety to pervious destruction. Fig. 7 and the Fig. 8 show the general condition, course of traverse, and boring hole position of the measurement section. Fig. 9 is a geology assumption figure in the bank of the 30.5-km point obtained from the detailed check result. It turns out that structure is very complicated.

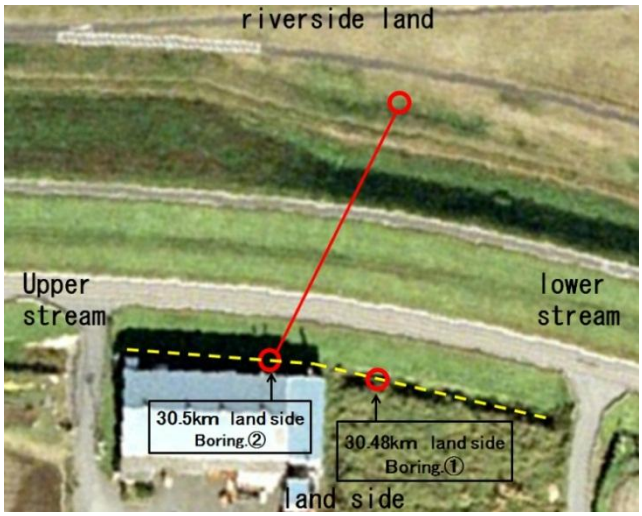

Fig. 7. The position of a course of traverse and a boring hole (Dashed line: One-meter Depth Temperature method lateral line, Round mark: The position of a drilling hole, Solid line: A 30.5-km point (Fig. 9))

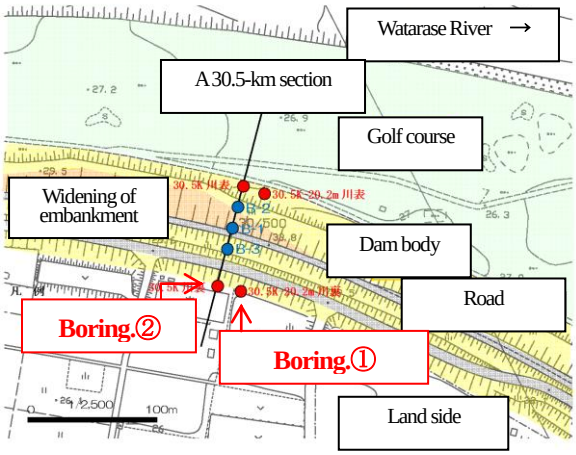

Fig. 8. The plan view of the measurement section

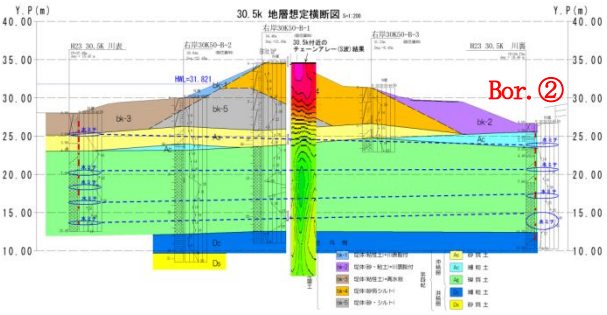

Fig. 9. The geology assumption figure in a 30.5-km bank (The section of the solid line in Fig.7 and Fig.8)

3.2. Various investigation results and comparison

The result of One-meter Depth Temperature method is shown in Fig. 10. A horizontal axis shows distance (km)and the vertical axis shows temperature(℃). Dashed lines are observations in summer and solid lines are observations in winter. It corresponds to a left-hand side vertical axis and a right-hand side vertical axis, respectively.

At a 30.48-km point, compared with the surrounding soil temperature, the result in summer showed low temperature and result in winter showed high temperature from Fig. 10. This indicates reaction of the groundwater. Moreover, since One-meter Depth Temperature will be 22 ℃ in summer and has become 18 ℃ in winter, groundwater temperature can be presumed to be about 20 ℃. One more point was selected for comparison examination etc. (30.5 km)

In these two points, the boring investigation and the Multipoint Temperature Logging method were performed. Fig. 11 and Fig. 12 show the results of the Multipoint Temperature Logging method. The range surrounded with the dashed line is the part which showed influence of the flowing groundwater. A change of colors show a change of a soil property.

First, at a 30.48-km point, the temperature restoration rate was indicated 60% or more in GL-7.1~8.1m, GL-9.1~10.2m, GL-11.6m, and GL-14.1m. It is shown that the flowing groundwater layer detected near depth GL-11.6 m is the groundwater which flowed from near depth GL-11.1 m. This result suggested that the water head in GL-11.1m

is lower than the water head near GL-11.6 m.

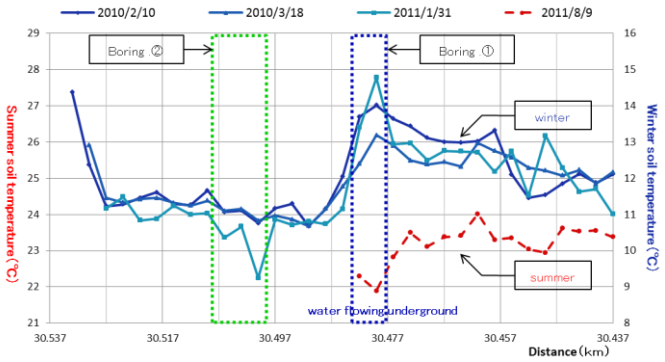

Fig. 10. The result of One-meter Depth Temperature method
(Dashed line: Observation in summer, Solid line: Observation in winter,
Dotted line: The position of a boring hole)

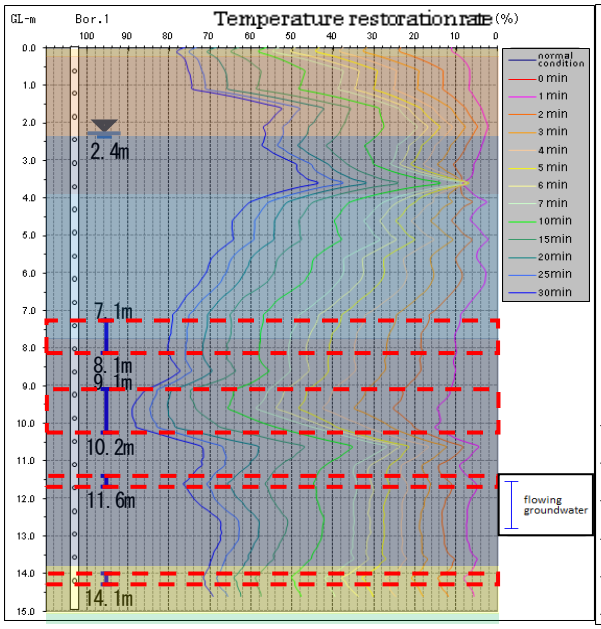

Fig. 10. A 30.48-km point, land side, boring①

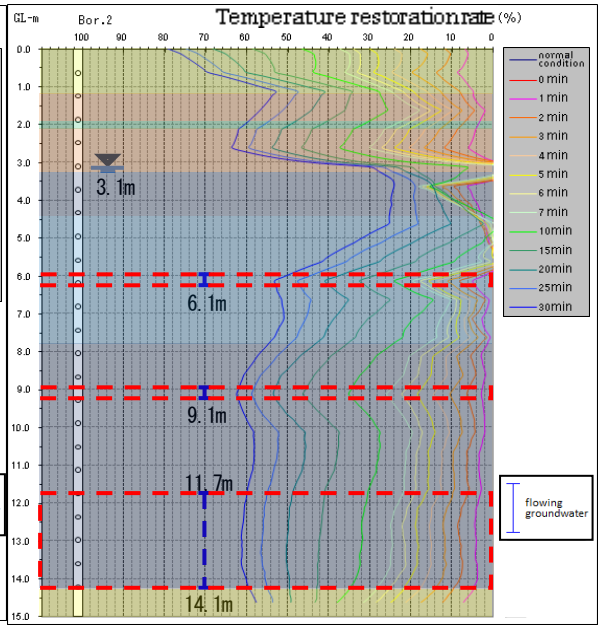

Fig. 11. A 30.5-km point, land side, borin②

Next, at a 30.5-km point, the temperature restoration rate showed about 60% in GL-6.1m (53.3%), GL-9.1m (62.6%), and GL-11.7~14.1m (60.0~61.5%). It is presumed that the weak flowing groundwater layer exists near these.

The following can say from the result of One-meter Depth Temperature method and the Multipoint Temperature Logging method.

- At the boring hole which had obtained result of the flowing groundwater layer by One-meter Depth Temperature method, result by Multipoint Temperature Logging method showed good agreement.
- The temperature of the normal condition of the Multipoint Temperature Logging method is 18~22 ℃, and was in agreement with the groundwater temperature currently guessed from One-meter Depth Temperature method.
- Correlativity is seen by the relation between change of a soil property, and change of temperature (temperature restoration rate).
- Even if the same assumed soil region, there is the indication of the flowing groundwater layer in not all region.

About the existence of the indication of the flowing groundwater layer existing in not all same layer type, comparison examination with the physical-properties value of a soil test was performed. (Fig. 12)The ranges surrounded with the dashed line are the part which showed the indication of the flowing groundwater layers. A change of colors show the

change of soil properties.

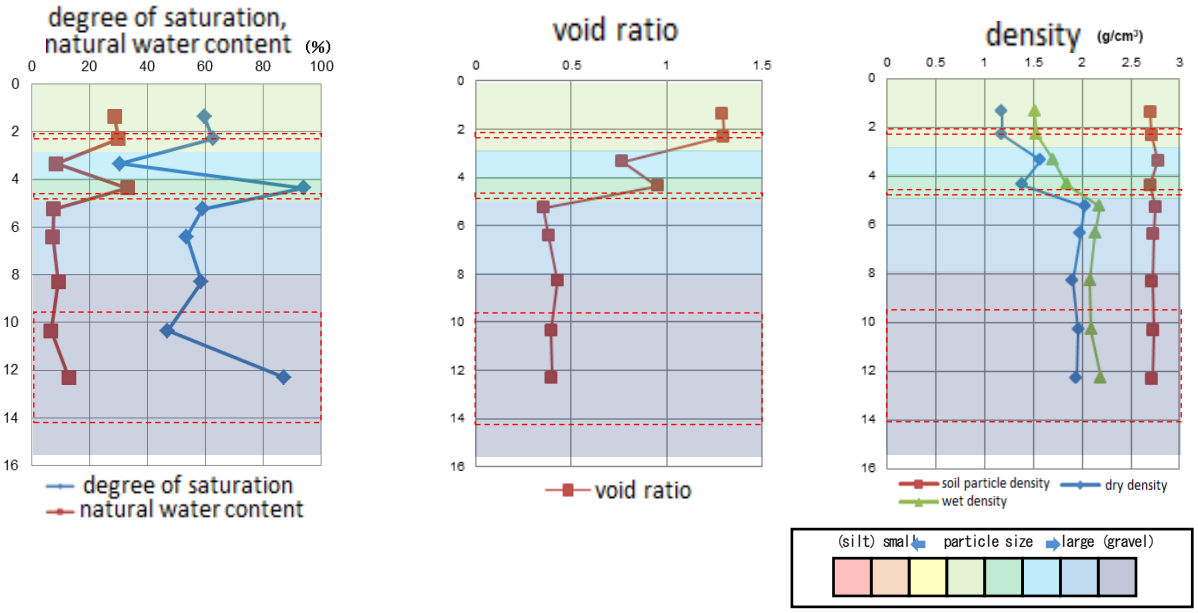

Fig. 12. Each physical-properties value and the relation of the indication of the flowing groundwater layer

The following can say from Fig. 12.

- The indication of the flowing groundwater layer was seen in the nature fine sand of silt, fine sand, and grit.
- In the place where the indication of the flowing groundwater layer exists, a degree of saturation and natural moisture content are high, and it is thought that groundwater exists.
- Density is low in the place where the indication of the flowing groundwater layer exists, and since the void ratio is large, it is thought that flowing groundwater exists.

4. Conclusion

In this study, on the bank of the WATARASE river where it was apprehensive about the safety to pervious destruction, field measurements were carried out and the flowing groundwater characteristic was examined. The obtained conclusion is shown below.

・The "flowing groundwater exploration method" was used for the actual riverbank, and the section with anxiety of base leakage of water has been pinpointed.

・Correlativity was seen by the relation of each physical-properties value of the indication of the flowing groundwater layer and a soil property.

・Good relationship between soil property and temperature (temperature restoration rate) was showed.

References

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