SP Monitoring at a Sea Dyke

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Introduction

SP has been widely used for the investigation of anomalous seepage in dams, sea dykes and waste disposal sites (BOGOSLOVSKY and OGILVY, 1971; OGILVY and BOGOSLOVSKY, 1969; SONG et al., 2005; TITOV et al, 2000). In this case, major origin of SP is the streaming potential generated by the flow of seepage water. Generally, it is known that SP voltage increases as seepage increases. In the sea dyke, leakage flow is very strong because of the great difference between rise and fall of the tide, which leads to great SP anomaly. However, it is really hard to define anomalous seepage zones from the SP profile measured at a particular time, since it fluctuates severely. Moreover, SP time sequences also demonstrate severe fluctuations at most of stations. To overcome this problem, we propose a simple but effective interpretation method of SP monitoring data.

SP monitoring

SP voltage in sea dykes is mainly generated by the flow of seepage water. Thus, SP voltage caused by subsurface current is directly related to the amount of seeping water. SP changes in time mean changes in current flow in the subsurface if changes in resistivity structure are negligible. The resistivity of the subsurface medium is highly variable, depending on the porosity, water content, temperature, etc. In the strict sense, the resistivity of subsurface changes when there are some changes in the flow of seepage water. In such a case, the interpretation of SP monitoring data becomes pretty hard because it requires the distribution of resistivity. This means that resistivity survey is additionally conducted to quantitatively interpret the SP monitoring data. If we assume that changes in resistivity structure with time are negligible, the problem becomes surprisingly simple.

From ohm's law, the potential is given as the product of current *I* and resistance *R*.

$$V = I \cdot R \tag{1}$$

If there is no change in resistance, potential change, ΔV, between time t_1 and t_2 is just the product of current change with time and resistance. Then, current change in time is directly proportional to potential change.

$$\Delta V = V_{t_2} - V_{t_1} \approx I_{t_2} \cdot R - I_{t_1} \cdot R = \Delta I \cdot R \tag{2}$$

From equation (2), SP voltage changes in time directly indicate the change in subsurface current caused by the changes in the flow of seepage water. Therefore, changes in SP voltage with time give helpful information to identify the leakage zones in sea dykes.

Data acquisition

SP voltages were monitored at a sea dyke that is located at the southern part of Korean peninsula. The dyke is 1528 m long and 6.6 m high and was constructed in 1997. First, we installed permanent electrodes at the flat step in the land side of the sea dyke. Instead of non-polarizing electrode, we used a stainless steel stake as an electrode because of the problem in maintenance. The station spacing was set to 20 m and the total length of the survey line was 1300 m. SP data were measured every six hours and transferred to office data base through CDMA communication.

Data processing

SP monitoring data were acquired from Feb. 8., 2011, 00:00, to Feb. 13., 2011, 12:00, measured every six hours at 62 stations and they are shown in Fig. 1. There are severe fluctuations with time at most of stations. Also, every profile at a particular time shows rapid changes. Thus it is impossible to identify anomalous seepage zone from both the profiles and time sequences.

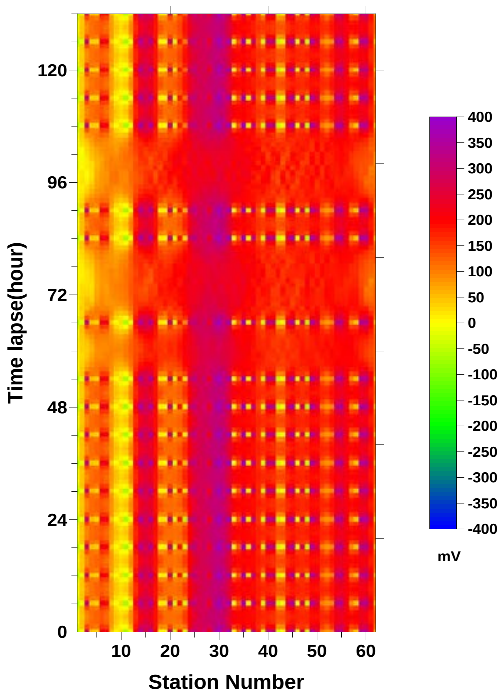

Fig. 1: SP monitoring data were acquired from Feb. 8., 2011, 00:00 to Feb.13., 2011, 12.00 measured every six hours at 62 stations.

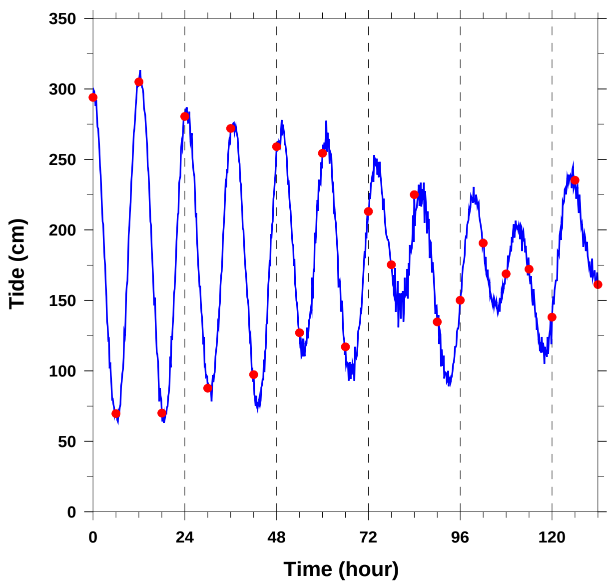

Fig. 2: Variation of tide levels with time at the sea measured every six houdyke. Red circles indicate SP measuring times.

Fig. 2 represents the tide level with time at the sea dyke. There is great difference between rise and fall of the tide: it reaches maximum 250 cm. The direction of seepage flow and the seepage rate are different at rise and fall of the tide. The amount of seepage water is closely related to the tide level: The higher tide level, the more seepage water. Thus, it is efficient to measure SP voltage when the tide level reaches maximum or minimum. In this case, the period of tide is smaller than 12 hours and SP was measured every six hours. Thus measurement time does not exactly match rise or fall time of the tide. At some times, there is no difference of tide levels between two adjacent measurements with time. In such a case, SP changes with time will be negligible and we may fail to find out the leakage zones.

Fig. 3 shows SP changes with time. For comparison, we added the tide level at the left panel. Most of the stations show negligible SP changes with time. However, station no. 23 shows greater SP change with time, having the positive and negative values repeatedly. The station is considered to be possibly a leakage zone. Station no. 38 seems to be another possible leakage zone although SP changes are weaker than those at station no. 23. As was mentioned, SP voltage should become great when the tide level reaches maximum or minimum. Correspondingly, SP changes in time also have to be great at the rise or fall of tide. However, there is no clear correlation between SP change and tide. This somewhat strange phenomenon will be studied in future.

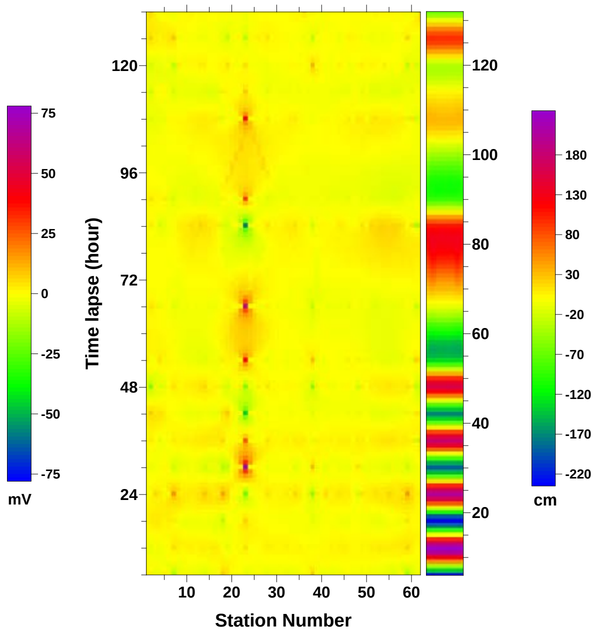

Fig. 3: SP changes with time. Tide level is added at the left panel for comparison

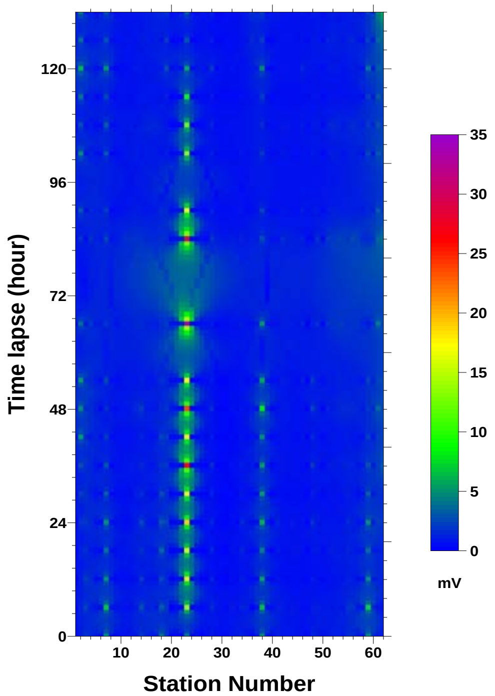

Fig. 4: RMS SP changes with time.

Calculation of SP changes from just two adjacent readings with time is very risky, especially when there are outliers. To suppress the outlier or noise, it looks to be more reliable to use SP changes calculated from RMS value of a moving time window. RMS SP changes from the SP data contained in the time window can be calculated from the following formula:

$$\Delta V_i = \frac{1}{2n-1}\sqrt{\sum_{j=-n}^{n}(V_{i+j}-V_i)^2}, \qquad (i=1,2,\cdots,N), \tag{3}$$

where ΔV_i is the SP change at the *i*th time. *n* and *N* indicate the size of time window and the total number of measurements with time, respectively. Fig. 4 represents RMS SP changes with time. We can find much more clear SP anomalies at the station no. 23 and 38. But the sign of RMS SP change is always positive.

We carried out visual inspection at the sea dyke and found some symptoms of leakages near the station no. 23 and 38, such as the loss and loosening of riprap at the sea side and formation of large openings caused by the loss of riprap.

Conclusions

Simple but effective interpretation method of SP monitoring data is proposed. SP changes with time are directly related to changes in seepage flow in sea dykes if changes in resistivity structure are negligible with time. Thus, leakage zones in a sea dyke can be effectively identified from the strong SP changes with time. Applying this method, two suspicious leakage zones were detected at a sea dyke and symptoms of leakage were found from afterward visual inspection. However, SP monitoring data does not show some correlation with tide. This should be studied in the future work.

Acknowledgements

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