Hydraulic Conductivity of Saturated Neogene Rocks Under Low Hydraulic Gradient

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1. Introduction

Hydraulic Conductivity (Permeability) is one of the most important soil parameters. In this study we estimated the horizontal hydraulic conductivity values of saturated Neogene rocks under low hydraulic gradient. Mainly we were focusing the trend of hydraulic conductivity value with various types of laboratory tests.

2. Samples and Measuring Apparatus

Samples were collected from Takahoko Formation at Rokkasho Village, Aomori Prefecture, Japan. In this site, Neogone Sedimentary rocks are covered with a Quaternary deposit in several meters thick. The Neogene sedimentary rocks consist of mudstone, sandstone and pumice tuff. With the exception of a several meters thick surface layer, the sedimentary rocks are fresh and do not exhibit cracks that would effect the ground water flow as a whole. The Quaternary deposit consists of volcanic ashes, terrace sand and alluvial low land sediment.

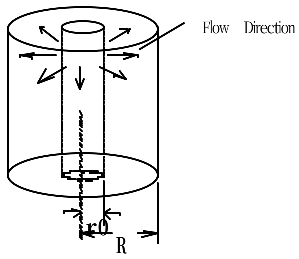

Fig :1 Rock Specimen

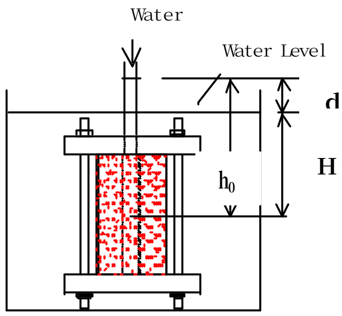

Fig :2 Test Equipment

Type of sample using in this experiment is as shown in Fig 1. Inner hole diameter is 1 cm, diameter of the sample is 5 cm and height of the sample is about 10 cm. Fig 2 shows the schematic view of test equipment to measure hydraulic conductivity of rocks. It is connected with the manometer by using 5 mm diameter tube. At the top and bottom plates, we used rubber rings sealed with watertight material to prevent the leakage.

3. Theory and Procedure

Samples are saturated with distilled water by using vacuum pump and put into the glass box in which filled with distilled water. Water flows from small inner hole drilled through the center of specimen toward outside by the pressure difference between inner hole and outside. Based on Darcy's Law the horizontal hydraulic conductivity of rock specimen can be estimated from the change in head of water level after some time and it can be calculated by using the theoretical equation below. K= horizontal hydraulic conductivity (m/s), Q= flow rate (m3/s), b= thickness of sample (m), R= radius of sample (m), r0= radius of inner hole (m)

$$K = \frac{Q}{2pb\Delta h} \ln \frac{R}{r_0}$$

4. Experimental Result

From the experimental results, we can draw a family of type curves of relation between hydraulic gradient and hydraulic conductivity of rock specimen as shown in Fig 3 and we can classify into three groups of type curves. Fig 4a, 4b and 4c present the three types of curves of different trends under low hydraulic gradient.

Fig 4a shows the values of hydraulic conductivity that are gradually decreased from high hydraulic gradient to low hydraulic gradient. The curve is rapidly changed at hydraulic gradient greater than 5. Fig 4b represents the second type curve, in which the hydraulic conductivity is suddenly changed under hydraulic gradient of less than 5. The last one shows no significant changes in hydraulic conductivity under high or low hydraulic gradient.

According to these results, the three types of hydraulic conductivity are not due to the change in rock specimen and any other effect occurred during the test time.

5. Additional Experimental Result

To make sure that the above discussion we considered the effect of air bubbles and contamination due to the minerals which can reduce the flow rate. For this reason we carried out the different types of experiment for the accuracy of our result. Fig 5 presents the same results of tests for one sample for two times under same condition.

Another possibility to deviate from our accuracy is due to the minerals, which are coming out from specimen into inner hole. In some cases, because of pressure difference between inner hole and outer surface due to the minerals, reverse osmosis flow may be occurred. Fig 6 presents the same trends of hydraulic conductivity in cases of water flows through the inner hole to outside and water flows outside to inner hole. It seems that the reverse flow may not occur in this experiment.

Key words: hydraulic conductivity, permeability, low hydraulic gradient, saturated Neogene rocks
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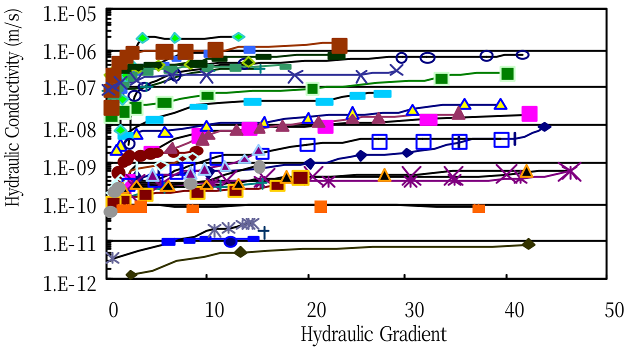


Fig : 3 - Permeability Test Result

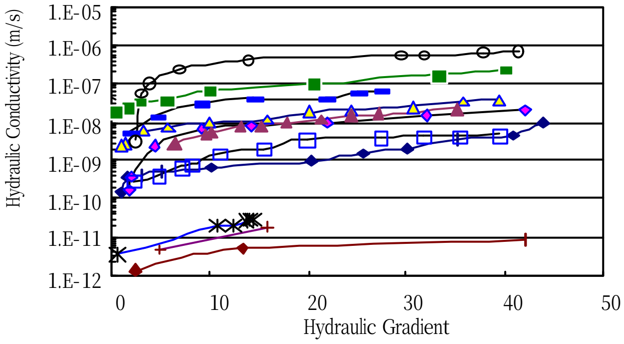


Fig : 4 - a Permeability Test Result for i > 5

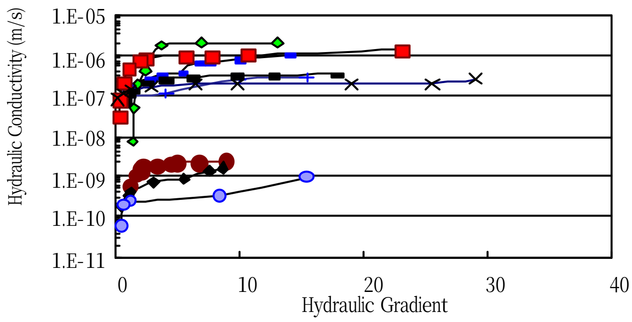


Fig : 4 - b Permeability Test Result for i < 5

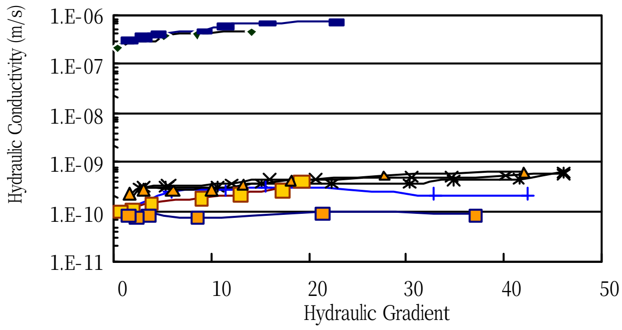
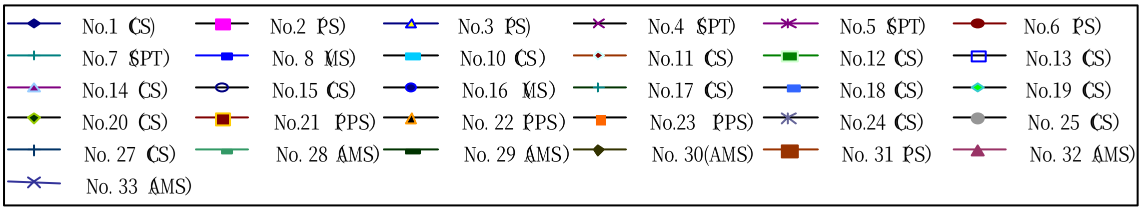


Fig : 4 - c Permeability Test Result for i is significantly small

Legend :

CS - Sandstone PS - Pumiceous Sandstone PPS -Pumiceous Sandstone
SPT - Sandy Pumice Tuff MS - Mudstone AMS - Alternation of Mudstone and Sandstone



6.Comparison between Horizontal and Vertical Hydraulic Conductivity

Generally, in the sedimentary layers of sand and clay sand, horizontal hydraulic conductivity is higher than the vertical one. Fig 9 presents the comparison between horizontal and vertical hydraulic conductivity under hydraulic gradient of 40.

Transient pulse technique was used to measure the vertical hydraulic conductivity. In this case horizontal hydraulic conductivity is not different from the vertical one except for sample No.1. Sample No.1 is sandstone, which includes thin layers of coarse sand. We can identify that the horizontal hydraulic conductivity is higher than the vertical one with small-scale sample. However, for pumiceous sandstone and sandy pumice tuff that are formed with volcanic rocks we can not identify with small scale scheme.

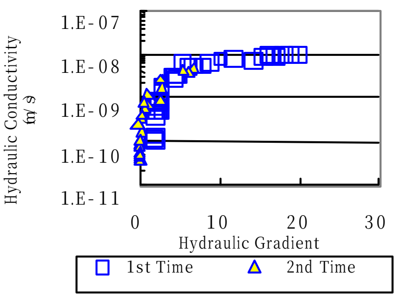


Fig : 5 Permeability by conducting two tests of the soil sample

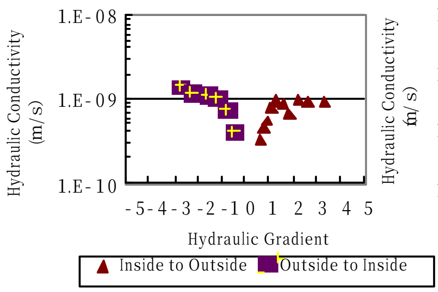


Fig : 6 Permeability influenced by Flow Direction

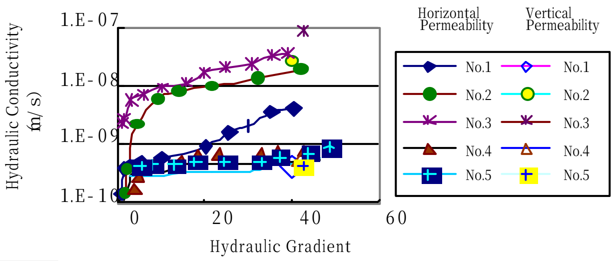


Fig:7 Comparison between Horizontal and Vertical Permeability

7. Conclusions

(1) There is no relation between horizontal hydraulic conductivity changes and types of rocks.
(2) From the results, hydraulic conductivity trends can be classified into three types under low hydraulic gradient.
(3) Accuracy of this experiment is good because of there was no air bubbles effect, contamination effect and evaporation effect during the test time.