Bearing Capacity of Sedimentary Soft Rocks Exhibiting Strain Softening Behavior

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1. Introduction

According to Terzaghi's bearing capacity formula, the coefficient of bearing capacity and bearing capacity differ depending on the failure mode of the ground (general shear failure, local shear failure)[1),2)], and the relationship between the load and the amount of footing settlement in both failure modes is classified by state of the soil condition (coarse / dense, hard / soft). In general shear failure, it is assumed that all points on the slip surface reach the ultimate state at the same time, whereas in local shear failure, the point where the ultimate state is reached increases with increasing load, and it is formed that the slip surface is expanded by progressive fracture. Therefore, it is necessary to determine the failure mode to calculate the bearing capacity of the ground, but the criterion has not been clarified so far. The stress-strain relationship of soil is classified into a strain softening type and a strain hardening type, and the bearing capacity problem is considered to correspond to general shear and local shear failure modes.

Diatomaceous soft rock is a material that shows remarkable strain softening irrespective of consolidation state[3)]. In evaluating the bearing capacity of this rock, it is reasonable to consider that the shear stress at the point where the shear stress locally reaches the shear strength according to the strain level before reaching the ultimate bearing capacity (q_d) decreases to the residual strength. However, the mechanical behavior after the peak shear strength has not been sufficiently investigated.

This research was conducted to confirm the results of last year's research, with the same conditions sample which were taken from the same location, except the specific location it could not be ensured where the sampling was taken. The effect of the diameter of the specimen on the bearing capacity of a 3.5 cm diameter circular footing was investigated, and the relationship between the shear strength obtained from the triaxial compression UU test and the results of the bearing test was discussed.

Table 1 Physical properties of samples

ρ_s (g/cm³)	ω_n (%)	ω_L (%)	ω_p (%)
2.183	120～130	172.7	94.7

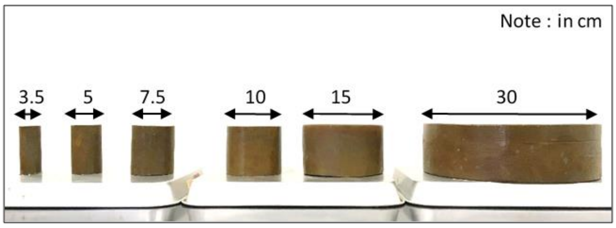

Fig.1 Test specimens

2. Samples and Experimental Methods

The sample is a homogenous diatomaceous earth (diatomaceous soft rock) collected in block form in Suzu City, Ishikawa Prefecture. Table 1 shows the physical properties of the samples. Specimen height (h) was fixed at 10 cm and diameter (d) was selected as 3.5, 5.0, 7.5, 10, 12.5, 15, 30, 35, 40 cm and stainless steel footing with a rough bottom with a diameter of 3.5 cm with the shear rate of 1.0 mm/min. Fig. 1 shows the test specimens, and Fig. 2 shows the view of the bearing capacity test conducted at 30 cm in diameter.

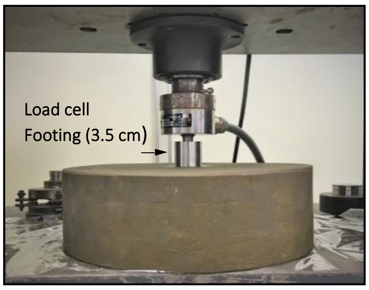

Fig.2 Test specimens 30 cm diameter

3. Experimental Results and Discussion

3.1 Triaxial UU Test Result

Fig. 3 shows the stress-strain relationship of the triaxial UU test. The figure (a) are the results of research conducted in the last year and for figure (b) are the results of the current research. In these two figures, the peak and residual deviator stress can be seen. The result of zero cell pressure from the last year is different from the other test results even though it was performed as a UU test instead of unconfined compression test. For the last year, the other maximum deviator stress, which is called as peak strength (q_p) is 2.0 to 2.3 MPa regardless of the cell pressure, and the current research for q_p is nearly same to the last year are 1.8 to 2.3 MPa with the axial strain at that time is approximately equal to 5%. Furthermore, the results of last year and current research show that the sample exhibits remarkable strain softening behavior, which is a characteristic of the sample, and all of them reach almost the same residual deviator stress, which is called as residual strength (q_r). Fig. 4 shows the Mohr's circles based on the peak strength and the residual strength, and the fracture envelope of $\varphi_u = 0$ can be drawn in the same way as observed with saturated clay except for zero cell pressure.

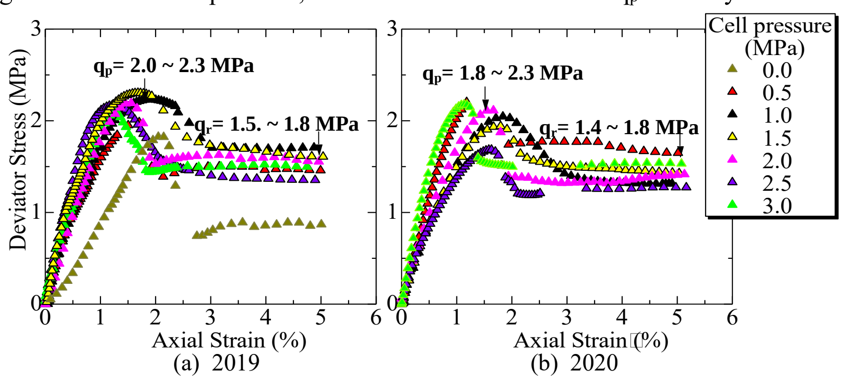

Fig. 3 Stress-strain relationship in triaxial UU test

Keywords: Diatomaceous Soft Rock, Triaxial UU Test, Bearing Capacity, Strain Softening, Residual Strength
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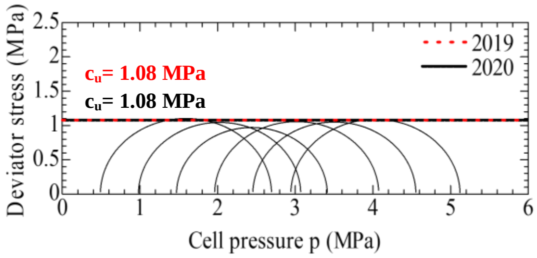
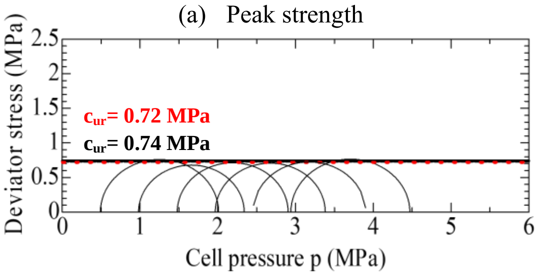
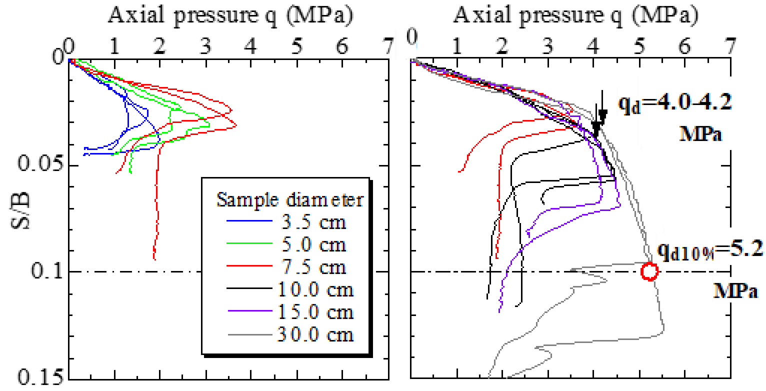


(a) Peak strength

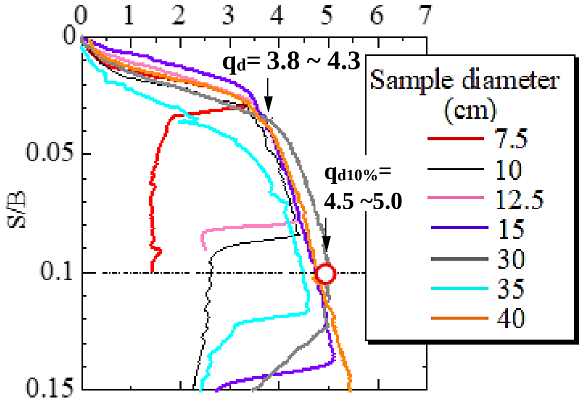


(b) Residual strength

Fig. 4 Mohr's circles for triaxial UU test



(a) 2019



(b) 2020

Fig. 5 q-S/B curve of bearing capacity test

For current research, undrained shear strength (c_u) is same to the last year is 1.08 MPa. The residual strength (c_{ur}) is nearly same for both of result is 0.72 MPa, which is about 70% of c_u. The ultimate bearing capacity (q_d) based on some bearing formulas using these values is compared with that obtained from the bearing test in the next section.

3.2 Results and Discussion of Bearing Capacity Test

Fig.5 shows the relationship between the axial pressure and the settlement ratio (settlement S / footing width B) of samples with the different diameters. The peak drop shape shown in Fig. 5 is shown up to 7.5 cm in diameter, in Fig. 5, but the yield point is confirmed when the diameter exceeds 10 cm. In the test under these conditions, it was confirmed that the diameter of the test specimen, for evaluating the bearing capacity equal to or higher than the yield stress must be at least three times the footing diameter. The ultimate bearing capacity (q_d) of the last year's research with a diameter more than 10 cm was 4.0 to 4.2 MPa, and the current research show 3.8 to 4.3 MPa. In the classic bearing formula under the test conditions, by substituting the c_u value of the UU test into the Terzaghi's equation, the last year and current research show for q_d have same value is 5.5 to 6.6 MPa, which is larger than the measured value. Therefore, using the c_{ur} value obtained from the residual strength (q_d), the last year research show q_d is equal 3.7 to 4.3 MPa, and 3.8 to 4.5 MPa as current research which was close to the measured value.

Table 2 The Results of Ultimate Bearing Capacity (Terzaghi's Equation)

	2019	2020
q_d (c_u)	5.5~6.6 MPa	5.5~6.6 MPa
q_d (c_{ur})	3.6~4.3 MPa	3.8~4.5 MPa

The red circle ($q_{d10\%}$) in Fig. 5 indicates that the q_d value at S/B=10 %. Last year research, 30 cm size diameter exceed the S/B=10% with the ultimate bearing capacity value ($q_{d10\%}$) was 5.2 MPa. However, for current research show more than 15 cm diameter size diameter exceed the S/B=10% with the ultimate bearing capacity value ($q_{d10\%}$) is equal 4.5 to 5 MPa. This value corresponds to the lower limit of the bearing capacity formula based on the c_u value.

4. Conclusion

The bearing capacity of diatomaceous soft rocks showing remarkable strain softening behavior was examined by the plate bearing test of specimens with different diameters. As a result,

1. Using a different size diameter of soft rock, the results of last year's research (2019) had the same results as this year's results.
2. The ultimate bearing capacity of this sample calculated by the bearing capacity formula (Terzaghi theory) is better to use the residual strength (c_{ur}) of UU test.

References

1) C.H.Dunn : Bearing Capacity of Soil, Manuals Corps of Engineers, U.S Army, 1958.
2) K. Miyakita and H. Maekawa : Mechanical properties of diatomaceous soft rock (diatomaceous earth) in Noto peninsula, Soil Mechanics and Foundation Engineering, 31(1), pp.83-88, 1983. (Japanese text)
3) Terzaghi, K. : Theoretical of Soil Mechanics, Willey, New York, 1943.