Inverse Analysis for Stiffness Factor of Landslide and its Application to Failure Prediction

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I. Introduction

The increment of groundwater level by rainfall or melted snow can be said one of the factors that generates landslide. Landslide slides because of water migration by the increment of groundwater level and formed slip surface in the inner part of landslide. Pore water pressure loading test was conducted as a model of landslide slope. The specimen used in this test is Fujinomori clay. The material parameters of the specimen are λ=0.113, κ=0.016 and M=1.41. This paper will discuss the behaviour of landslide and the failure prediction using the stiffness factor.

II. Yield Point and Failure Point

Figure 1 shows the stress path (upper figure) and the void ratio path (lower figure) for the case of over consolidated ratio *OCR* = 2 and shear stress q = 80 kPa. This study defines yield point at the point where e – p' line deviates from elastic swelling line. Pore water pressure loading test shows that due to pore water pressure loading, the specimen becomes over consolidated, and dilatancy (plastic deformation) occurred after reaching the yield stress. In the stress path, the yield point exists on the critical state line

When the pore water pressure is loaded more, the stress displacement increased rapidly and the deviator stress could not be maintained at constant anymore. The failure point is defined at the point where deviator stress declined. Deviator stress declines after reaching the failure point shows a similar phenomenon in drained test of over consolidated clay where after reaching the peak strength, shear stress decreases.

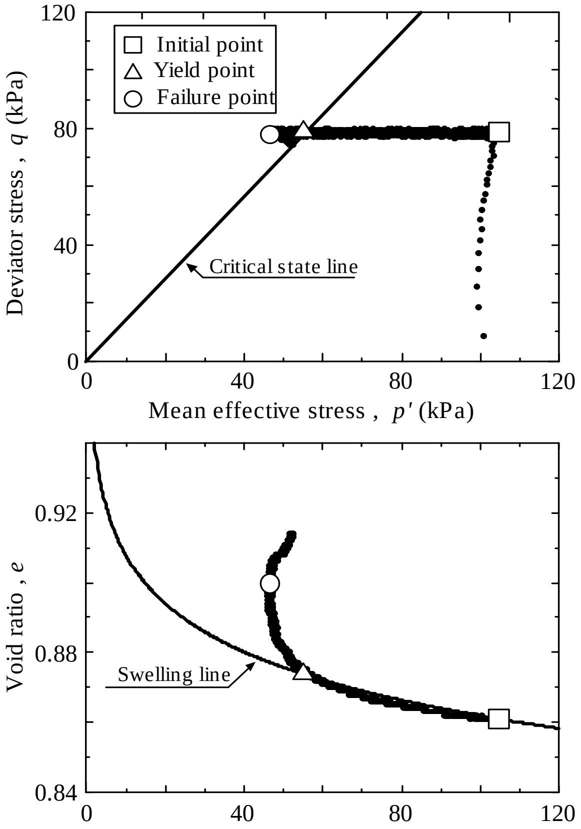

Fig.1 Stress path and void ratio path

III. Time Dependency Behaviour

Figure 2 shows the result of the pore water pressure loading test where *OCR*=1 and the deviator stress varied. In this test, specimens were loaded every 2kPa of pore water pressure loading from the bottom to the top of the specimens. As shown in the figure, the measured pore water pressure formed a convex relationship with time at each stage of loading. This is because a certain finite time is necessary for pore water pressure to transmit from the bottom to the top of the specimens.

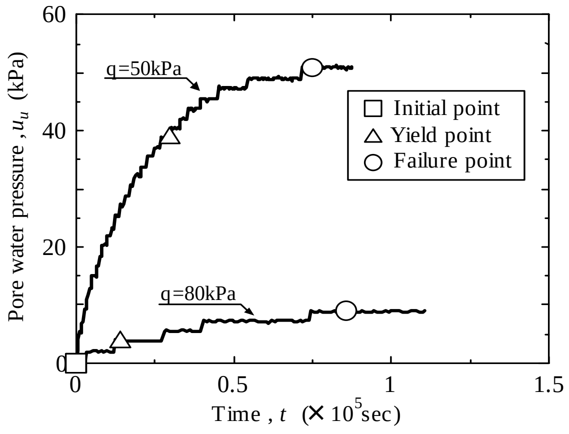

Fig.2 Measured pore water pressure

IV. Stiffness Factor and Failure Prediction

Stiffness factor is a ratio between load and displacement. But in this study, stiffness factor is defined as ratio between the pore water pressure and the axial strain. The stiffness factor is divided into two that are the tangent modulus and the secant modulus. From these modulus, landslides failure prediction is carried out. Fig.3 shows the relationship between tangent modulus and time. As shown in the figure, the stiffness modulus shows a constant behaviour, but after reaching the yield point, it declined. Near the failure point, the stiffness factor declining to zero and expressing the shear behaviour almost accurately.

The secant modulus is also considered as the stiffness factor (ref. Fig4). This modulus shows almost the same behaviour with the tangent modulus. The dispersion in the secant modulus is smaller than the tangent modulus and seems to be more stable. After reaching the yield point, the secant modulus declining but the failure point not necessarily reach zero. This is the characteristic of the secant modulus.

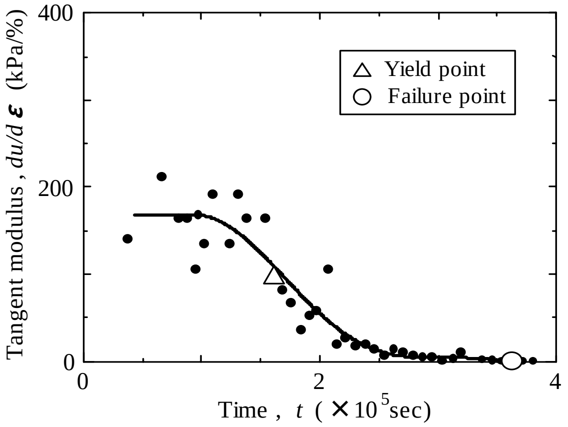

Fig.3 Tangent modules of stiffness factor

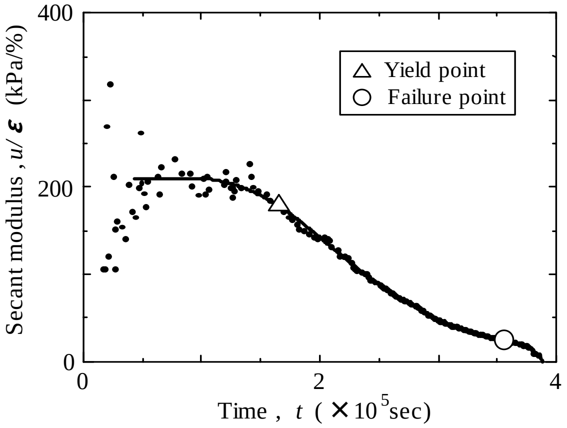

Fig.4 Secant modulus of stiffness factor

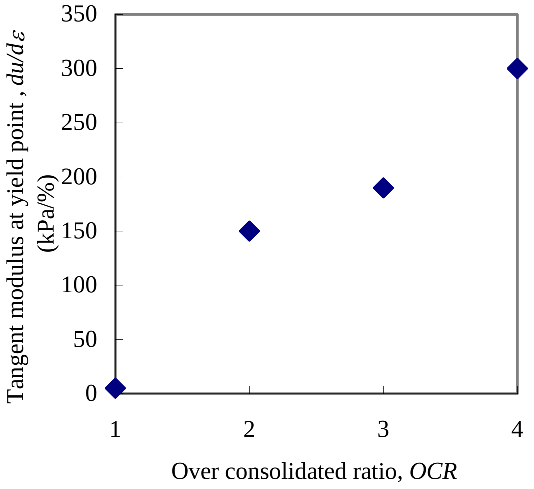

Fig.5 Tangent modulus at yield point against *OCR*

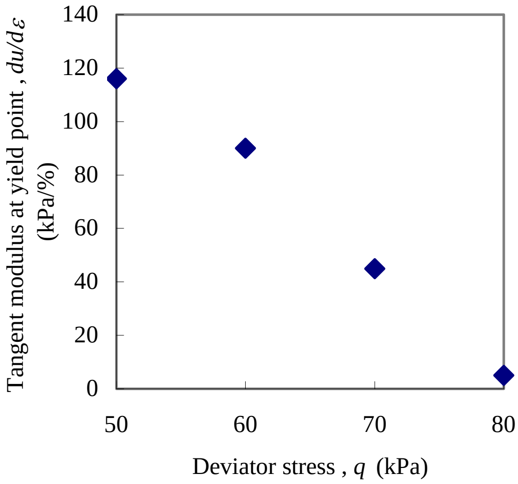

Fig. 6 Tangent modulus at yield point against *q*

As the value of the over consolidation ratio increases, the materials are stiffer. As shown in Fig.5, the bigger value of over consolidation ratio properly, the bigger value of the stiffness factor at yield point. By this, it can be said that the stiffness factor expresses soils stiffness. In Fig.6, the value of stiffness factor at yield point decreases along with the increment of deviator stress. This means that the larger stress is loaded to a specimen, soil stress greatly inclined.

V. Conclusion

The pore water pressure loading test was carried out to investigate the application of the stiffness factor regarding the effective stress. The stiffness factor regarding the effective stress is defined as the ratio between the strain and the pore water pressure. When the stiffness factor is zero, the specimen is considered failed. This predicts the landslides failure.

Reference

Keiichiro Saito (2002) *Experimental examination on landslide time dependency behaviour due to pore water pressure loading test*, Master thesis, Nagaoka University of Technology (*in Japanese*)