Evaluation of Non-uniformity of Specimen During Hollow Torsional Test

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Abstract. Using the proposed evaluating method, the variation of non-uniformity of the mean effective stress and the stress ratio and their distribution along the radius direction are discussed and explained in detail. It is found that there are several peak for the non-uniformity of mean effective stress but only one peak for the stress ratio. As the apparent shear strain increases, the distribution of mean effective stress and stress ratio along the radius also varies and the outer is always faster than the inner.

1. Introduction

In order to simulate the mechanical properties of the soil and validate the availability of the given constitutive model, many kinds of indoor experiments have been proposed to reproduce the mechanical behavior under different stress or strain paths. Usually there are plane strain experiments, one-dimensional test and triaxial compression/extension test and the most popular test would be the triaxial compression test. However, the stress state in the triaxial test cannot be regarded as a true three-dimensional state and it is not suitable to verify the three dimensional constitutive model. The hollow torsion test is usually regarded to be the most similar to the element-wise sample to research the mechanical response of certain soil (Asaoka and Noda 1995, Jin et al. 2010). However, during the torsion test there would be non-uniform deformation which would influence the apparent behavior of the specimen (Hight et al. 1983, Sayao and Vaid 1996). Xu et al. (2016) proposed an evaluating method to judge the non-uniformity quantitatively.

In this paper, the non-uniformity of the stress ratio (ratio between the deviator stress and mean effective stress) and the mean effective stress are shown. The variations of two parameters are explained in detail.

2. Mean effective stress

Figure 1 shows the variation of the non-uniformity of mean effective stress. The variation curve is divided into four sections with lines a, b, c by marking the maximum deviation and the minimum deviation. For the three extreme value the apparent shear strain of the specimen is 1.83%, 3.54% and 11.0% respectively. The variation of the non-uniformity of the mean effective stress is shown in Figure 2 and the soil specimen is considered as an entire integrate. In the figure, the mean of a, b and c
are exactly the same as the above content. Figure 3 gives the distribution of the mean effective stress of the node in the radius direction for various shear strain. It can be seen that the variation of mean effective stress at the internal space is controlled by the tendency of mean effective stress at the outside. The detailed explanation of the development of the deviation of the mean effective stress are discussed in the following:

1) As shown in Figure 3, the deviation of the mean effective stress is zero initially due to the uniform distribution of cell pressure. With the development of shear strain the effective stress path increases and the mean effective stress starts to decrease. However, because the mean effective stress of at the outside decreases rapidly the magnitude of the non-uniformity starts to enlarge gradually until the shear strain is 1.83%, which is around the line a;

2) In Figure 2 when the mean effective stress at the outside gets line b, the volumetric dilatancy occurs and the mean effective stress becomes to increase but the mean effective stress at the internal radius is slower than that at the outside. The degree of the non-uniformity becomes almost zero when the shear strain is 3.54%;

3) When the mean effective stress at the inside and outside radius goes through the minimum value, the magnitude of the non-uniformity becomes larger as the different pace of the mean effective stress at inside and outside.

4) Due to the rapid variation, the mean effective stress at outside reaches the critical state earlier than that at inside and then it keeps invariable. Then the nonuniformity starts to decline from line c and the shear strain is 11%.

Figure 1. Relationship between deviation of mean effective stress and shear strain.

Figure 2. Variation of mean effective stress
Figure 3. Variation of mean effective stress along radius.

Based on the above analysis, the nonuniformity of the mean effective stress firstly gets the maximum value and then starts to decrease until the minimum value. Due to the influence of the soil-water couple effect, the mean effective stress behaviors differently.

3. Stress ratio

Figure 4 demonstrates the nonuniformity of the stress ratio and line a represents the location of the maximum value which corresponds to 2.45% shear strain. As can be seen, the stress ratio increases fast at the initial stage as the shear strain increases and then reaches the maximum value which follows the decreases. Thus, if the stress ratio at outside and inside increases the magnitude of the nonuniformity would also incline. The difference of the stress ratio between the outside and the inside becomes small if the stress ratio at outside decreases. At last, if the stress ratio increases until the critical line the nonuniformity of the stress ratio becomes to zero again.
Figure 4. Variation of nonuniformity of stress ratio

Figure 5. Variation of stress ratio

(1)
Figure 6. Variation of stress ratio along radius

Figure 6 gives the distribution of the stress ratio from inside to outside. Additionally, the threshold between strain hardening and strain softening, the stress ratio and the threshold between plastic expansion and plastic compression are shown in Figure 7 considering the development of the shear strain. As can be seen, the soil specimen firstly expresses strain hardening accompanying with plastic compression and then becomes strain softening accompanying with plastic expansion. The variation of the parameters at outside is faster than that at the inside.
Figure 7  Relationship of $\eta$, $M$, $M_s$ along radius
Similarly, Figures 8-10 show the magnitude of the nonuniformity of the shear strain and the distribution of the shear strain along radius respectively.

4. Conclusions
In this paper, the variations of nonuniformity of the stress ratio and the mean effective stress along with the apparent behavior are discussed in detail. Moreover, the magnitude and distribution of above variables along the radius directions at different stages are also explained. The conclusions are as follows:

1. The magnitude of the nonuniformity of mean effective stress at the initial stages increases fast until the maximum and then begins to decrease to the minimum value. Due to the influence of the soil-water couple effect, the mean effective stress behaviors differently.

2. The stress ratio increases fast at the initial stage as the shear strain increases and then reaches the maximum value which follows the decrease. Thus, if the stress ratio at outside and inside increases the magnitude of the nonuniformity would also incline.

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