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Technical Note

Limit of crack depth in K_{IC} testing for a clay

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ABSTRACT

Fracture toughness (K_{IC}) is a very important parameter to evaluate fracture behavior of materials. Three-point bending (TPB) test on a single edge cracked beam (SECB) is often used to determine the value of K_{IC} of soils. Depth of initial crack (a) of the SECB specimen may affect the tested value of K_{IC}, limit of crack depth is therefore necessary in order to obtain the value of K_{IC}. In this study, a red clay, distributed widely in south-west of China, was used to investigate the limit. Three-group TPB tests on 63 SECB specimens with different dimensions and properties were carried out. Based on the testing results, the limit of crack depth for the clay, i.e. the ratio of initial crack depth to specimen width a/W = 0.3–0.6, was suggested.

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1. Introduction

Three-point bending (TPB) test suggested by ASTM Standard E399-12 [1] was often used to determine fracture toughness (K_{IC}) of soils by many investigators such as Sture et al. [2], Aluko and Chandler [3] and Wang [4]. In the TPB test, the specimen is a single edge cracked beam (SECB) (Fig. 1). In order to ensure linear elastic deformation and minimize the size effect of the specimen, some restrictions on the dimension of SECB specimen should be meted. The restrictions include the ratio of effective length to width $S/W = 4$ and one of width to thickness $W/B = 2$. Under the conditions, stress intensity factor (K_I) can be obtained by ASTM Standard E399-12 [1]:

$$K_I = \frac{PS}{BW^{3/2}} \frac{3\left(\frac{a}{W}\right)^{1/2}\left[1.99 - \left(\frac{a}{W}\right)\left(1-\frac{a}{W}\right)\left(2.15 - 3.93\frac{a}{W} + 2.7\frac{a^2}{W^2}\right)\right]}{2\left(1+\frac{2a}{W}\right)\left(1-\frac{a}{W}\right)^{3/2}} \quad (1)$$

where P is the load applied on SECB specimen; and a is the depth of initial crack.

When the value of P equals the critical load, the value of K_I calculated from Eq. (1) equals the value of K_{IC}. The value of K_{IC} calculated from Eq. (1) may be related to the value of a/W. The value of K_{IC}, as a mechanical parameter of material, should be independent on the value of a/W. In order to obtain the value of K_{IC}, the value of a/W was often limited by investigators. For instance, the value of a/W was 0.33–0.59 for a cemented sand in the works of Sture et al. [2], 0.45–0.55 for brittle agricultural soils in the works of Aluko and Chandler [3], 0.20–0.60 for soft rocks in the works of Haberfield and Johnston [5], 0.40–0.70 for frozen soils in the works of Li and Yang [6], and 0.45–0.55 for a silty clay in the works of Wang et al. [7].

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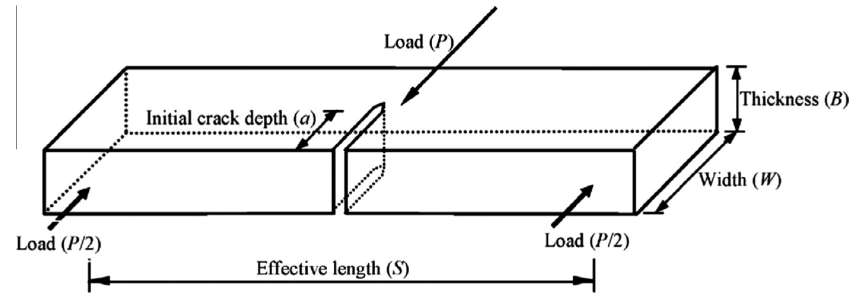

Fig. 1. Single edge cracked beam in three-point bending test.

In order to maintain constraint in K_{IC} testing of bend specimens, the crack depth should be limited [8], but so far, without any limit of crack depth in K_{IC} testing on SECB specimens for soils was reported. In the present study, the limit of crack depth in K_{IC} testing for a red clay was investigated by the TPB test.

2. Tested clay

A red clay, distributed widely in south-west of China and used usually as a material to fill seepage barrier, was used. Particle size distribution (PSD) curve of the clay is shown in Fig. 2. The maximum particle size of the clay is about 0.138 mm. The basic physical properties of the clay are as follows: specific gravity $G_S = 2.75$, plasticity index $I_P = 18.4$, liquid limit $W_L = 39.5\%$, plastic limit $W_P = 21.1\%$, maximum dry density 1.71 g/cm^3 and optimum moisture content 15.12%.

3. Testing scheme

The TPB test shown in Fig. 1 and described by Wang et al. [7] was used to determine the value of K_{IC} of the clay. In order to investigate the effects of the value of a/W on the value of K_{IC} calculated from Eq. (1), three-group TPB tests on 66 SECB specimens were carried out. The three-group TPB tests were called as the small size TPB test (1), small size TPB test (2) and large size TPB test, respectively. The 66 SECB specimens could be divided into two groups based on their dimensions or properties. The detailed dimensions and properties of SECB specimens tested in the three-group TPB tests were listed in Table 1.

4. Testing results

Fig. 3 shows typical curves of load versus displacement from the small size TPB test (1) on the SECB specimens with $a/W = 0.2$. It is clear from the plots that, before the value of P reaches its peak, the relationship of load against displacement is

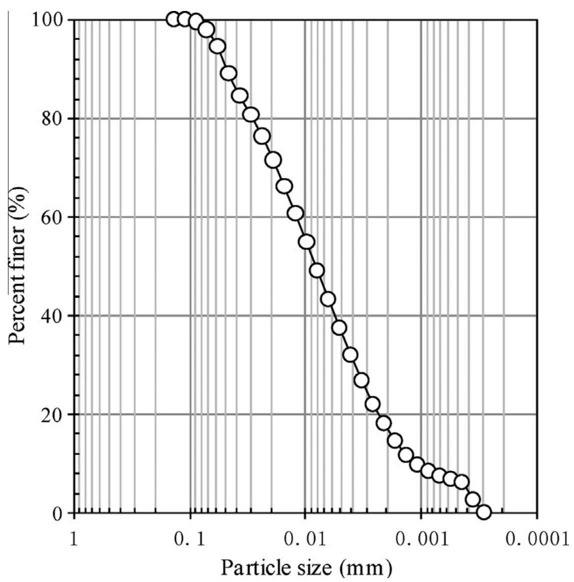

Fig. 2. Particle size distribution curve of tested clay.

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