EXPERIMENTAL INVESTIGATION ON CONCRETE SHEAR CRACK EXTENSION

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Summary Most interests about concrete mode-Ⅱ fracture primarily focus on four-point specimens and Brazilian disk specimens, but there are many debates about printed results. This paper tries to present a detail investigation on these two specimens. The whole evolution process of crack initiation and propagation trajectory of two specimens are presented and discussed, and the fracture toughness is calculated.

Introduction

The four-point-shear geometry was first adopted by Arrea & Ingraffea[1] to investigat the concrete material. Banzant & Pfeiffer[2] proposed a double-edge-notched beam geometry. The same geometry was adopted by Melin[3]. Hao et al[4] give a combined experimental and numerical study on double-edge-notch concrete beams, this specimens also were studied by Ingraffea & Pathaki[4], Pietro Bocca et al[5], Enrico et al[6], A. Carpinteri et al[7], Geers et al[8,9]. The researchers' different conclusions contradict to each other. The Brazilian disk specimens also have been investigated by many researchers [10,11] with different materials.

To give a comprehensive analysis about the fracture mechanism of two kind concrete specimens, this paper provides the whole evolution process from crack initiation and propagation to catastrophe in both cases of concrete four-point-shear specimens and Brazilian disk specimens. Our interest focuses on trying to reveal the concrete mode-Ⅱ fracture mechanism according to a combined study on concrete four-point-shear specimens and Brazilian disk specimens. The values of fracture toughness of two kind specimens are calculated.

Description of test

Material: 525# silicate cement; river sand; limestone coarse aggregate (size is 5~10mm).

Cement: water: fine aggregate: coarse aggregate = 1:0.53:2.06:3.17

The specimens were cured in water bath for 7 days and then stored in laboratory conditions with temperature $+18\pm2°C$ and 90% relative humidity for 21 days. After 28 days, the strength and fracture characteristics were determined. The compressive strength is $39.8MPa$; internal friction angle is $23°$; tension strength is $3.06MPa$; Elastic modulus $E=29.7GPa$; Poisson ratio is 0.2; Mode-Ⅰ fracture toughness is $0.701MPa$. The geometries of experiments for four-point shear specimens and Brazilian disk specimens are respectively shown in fig.1 and fig.2. The loading rate applied was16.3N/s , and $s_2=2s_1$.

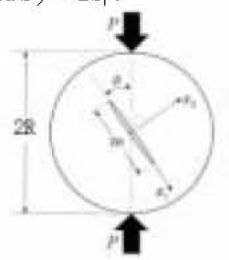

Fig.1 Brazilian disk specimens

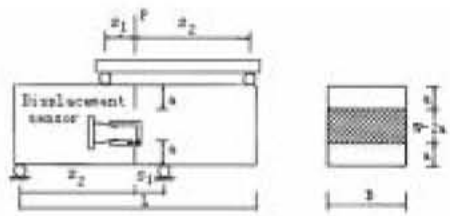

Fig.2 Four-point-shear specimens

Four-point shear specimens

In fig.3, a representative result of concrete four-point specimens is shown. The final main crack trajectory is that a crack at an angle with loading surface started at the under crack tip, then extend to the loading point. This result is agreed with other results of literatures.

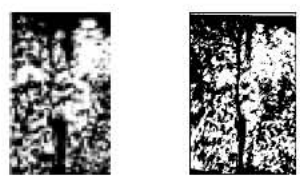

Fig.3 crack propagation trajectory of concrete four-point-shear specimens for $s_1=15mm$

Fig.4 shows the result when s_1 is $5mm$. In this case, a crack initiated at an angle with loading surface from the under crack tip, then it extend stably and turned to the direction paralleling to the loading surface, finally this initiation crack connected with the crack initiated from the up-crack tip and led to the specimen's failure. This fracture mode looks like shear fracture from macro-level, but the initiation direction did not parallel to the direction of loading or the direction of shear stress. The decreasing of the distance between loading point to crack surface did not change the fracture mode of specimens, it only decreased the crack propagation angle but did not obtain the pure mode-Ⅱ fracture. The critical stress intensity factors ratio K_{IIC}/K_{IC} is about 0.6~0.7 and agreed with the results of literatures.

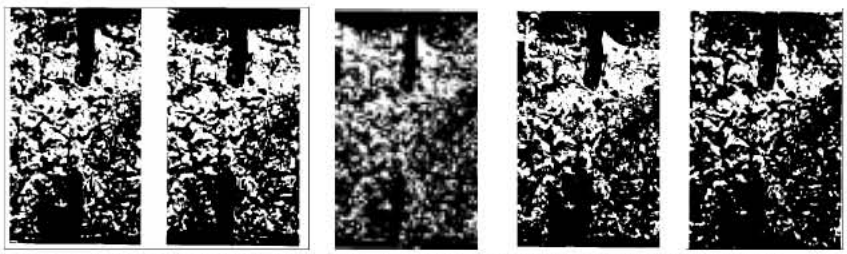

Fig.4 crack propagation trajectory of concrete four-point-shear specimens for $s_1 = 5$mm

Brazilian disk specimens

The radius R of specimen is $150mm$, the thickness B is 30mm. Because the K_{II} in the case of slope angle $\varphi = 15°$ increases most quickly than any other angle, and when the ratio of half crack length a with the radius R is 0.75, K_{I} almost equals to zero. So we significantly study this case.

The representative result is shown in Fig.6. A crack at an angle with crack surface initiated from two-crack tip. Then they continued to extend until they get to the load point. This result is agreed with that of other literatures[12]. Another interest result was also observed that when the initiation cracks from crack tips extended to some length, other two cracks from the boundary were induced. These two cracks should be resulted from the effect of boundary. Ratio $K_{\text{II}C}/K_{\text{I}C}$ is about 0.70~0.84 and larger than the results of four-point-shear specimens because of the pressure occurring near the tips of cracks.

Fig.6 crack propagation trajectory of Brazilian disk specimens

Discussions

In the case of concrete four-point-shear specimens, the orientation of crack extension is not at the direction of shear stress, and the fracture is resulted from the combined influence of mode-Ⅰbehaviours and mode-Ⅱbehaviours. The Ratio $K_{\text{II}C}/K_{\text{I}C}$ is agreed with the results of mixed mode of mode-Ⅰand mode-Ⅱ. It is difficult to achieve the mode-Ⅱ fracture with this specimen.

The crack propagation trajectory of concrete Brazilian disk specimens was agreed with other literature's[7] investigation with rock or other materials. In this case, the ratio of $K_{\text{II}C}/K_{\text{I}C}$ is larger than the results of four-point-shear specimens, but the crack initiation is not the true mode-Ⅱ fracture, it also includes the combined influence of mode-Ⅰand mode-Ⅱbehaviours.

To achieve the crack sliding initiation, there must be one measure to take to arrest the crack opening initiation in both cases of four-point-shear test and Brazilian disk test.

Reference

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