Shear Fracture - Testing Configuration for Cement Paste in Mode II

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Abstract: This article is focused on different ways of testing in mode II. There are presented three basic modes of a shear. The best way how to test the fracture mode II and determinate the critical factor K_{II} of cement paste beams is investigated here. Several methods are presented and the test based on a theory of the double-edge notched infinite plate is described in detail.

Keywords: shear fracture; mode II; experimental; fracture mechanics.

1 Introduction

The shear failure is a fundamental problem in practical engineering. Nowadays, various empirical formulae for evaluating the shear loading capacity are given. They were developed with using experimental data. In fact, this failure problem is a typical brittle fracture. Therefore, several researchers attempted to apply fracture mechanics to the shear failure for gaining a satisfactory physical model of the shear fracture.

In order to understand well the behaviour of concrete and the shear load, mode II testing needs to be performed for measuring mode II fracture toughness K_{II} and mode II fracture energy G_{IIF} of concrete materials. In practical engineering structures, it can be presented on a door-case in a building under the shear forces, the mode II fracture parameters can be directly applied to analysis. This article presents several methods for testing in the mode II and the double-edge notched infinite plate is described in detail here.

2 Mode II Tests for Concrete Materials

2.1 Fracture Modes

In general, there are three modes of the fracture failure shown in Fig. 1 - mode I opening, mode - II sliding, mode III - tearing. The combination failure in the mode I and the mode II is the main problem of testing mode II, so called a mix-mode. Each mode has its own stress factor intensity K. These factors represent the anasymptotic sphere of stress in the area of the crack mouth [2].

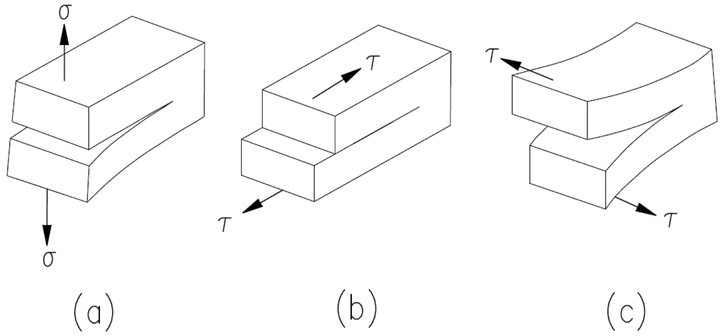

Fig.1: Modes of fracture failure.

2.2 Different Mode II Testing Configurations

In last years, many researchers paid attention on seeking mode II tests without mode I component supplement. As it turns out, not only the geometry but also the way of loading is important, equally, the geometry affecting the beam also affecting the test. Various methods were designed, some of them are shown in Fig. 2. First of all, Fig. 2a shows the theoretical pure stresses along the crack which is envisaged by testing but cannot be realized. Fig. 2b is designed by Iosipescu for metals and a welded joint, it seems to be a good solution but it came out, that the results are quite controversial and there is a thought that mode I has an influence in this test.

Fig. 2c - a push-off beam by Mattocky and Hawkins is originally presumed for testing concrete, but numerical studies have shown, that this is a mix-mode problem. The axisymmetric punch-though specimen (Fig. 2d) by Tada was used on mortar and concrete due to its easy handing, however there are large tensile stresses occured at the crack tip.

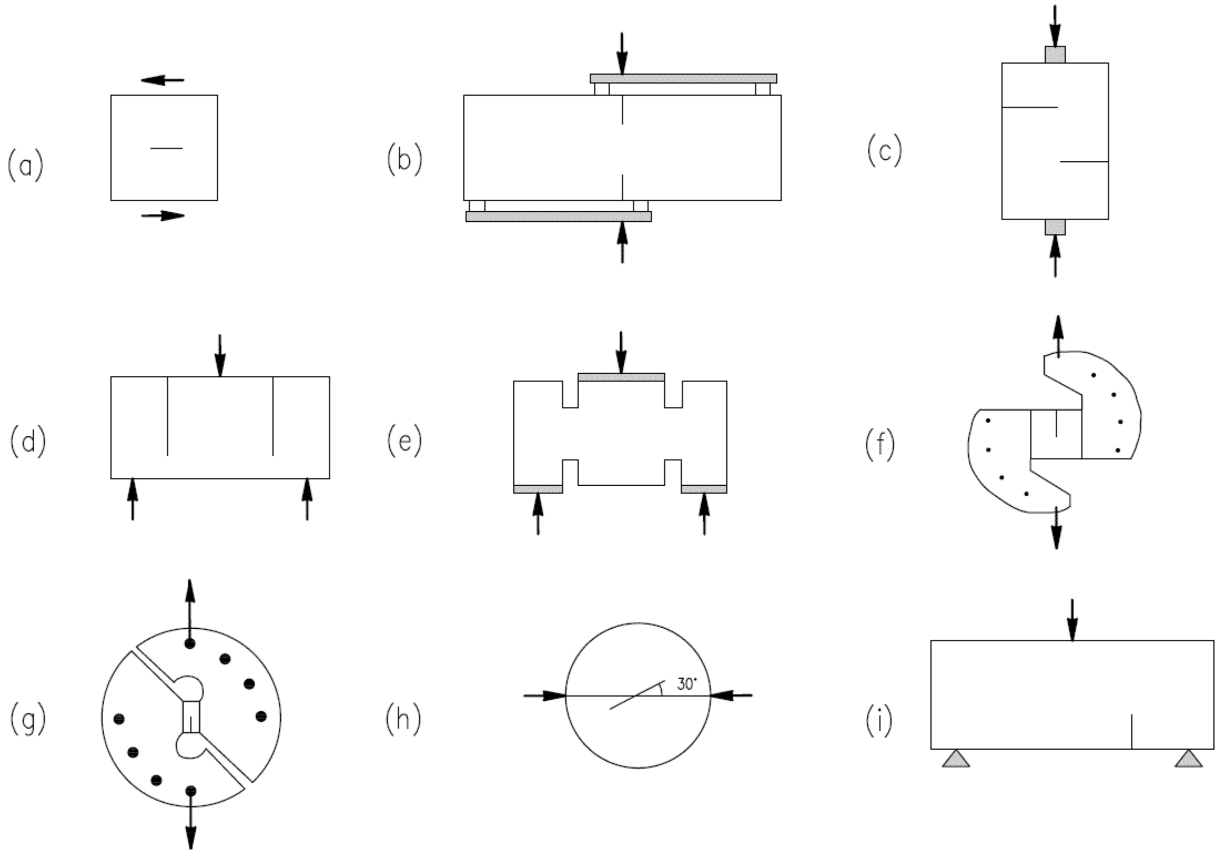

Fig. 2: Testing configuration for mode II

For a rock core testing, the cylindrical specimen with four notches (Fig. 2e) gives mixed-mode results. Fig. 2f - Although there are several methods proposed for mode II testing, none of them produces a pure mode II situation. That was the reason why Shilang Xu and W. Reinhardt carried out a new research project for an improved testing to study pure shear fracture of concrete.

Fig. 2g shows testing devices which allow various mixed combinations by rotation of the holder. Fig. 2g is not suitable for concrete, Fig. 2h designed by Irobe and Pen and finally the off-centre notched beam specimen by Jenq and Shah for studding mix-modes (Fig. 2i) [1, 3].

2.3 The Double-Edge Notched Specimen

Theoretical analysis was carried out to propose an improved testing method. The double-edge notched plate (Fig. 3) under the in-plane tensile loading seems to be appropriate, in both x-direction and y-direction the plate is infinite with unit thickness, the length of the ligament 2a is finite, but the lengths of double-edge notches are infinite. For such cases there is a formula of stress intensity factors as follows, and it is important to notice that K_I vanishes and K_{II} remains as the only one stress component.

$$K_I = 0 \tag{1}$$

$$K_{II} = \frac{\sigma}{4}\sqrt{\pi a} \tag{2}$$

The plane is still infinite in x-direction but finite in y-direction, determined by length w (Fig.3). If we take a half of the strip, the stress distribution along the symmetry axis of the strip could be assumed to be linear distribution. Using the relation between the stress intensity factor and J-integral, we can get the final formulae for K_{II} for a specimen with finite size [4, 5].

$$K_{II} = \frac{\sigma}{4}\sqrt{w} \tag{3}$$

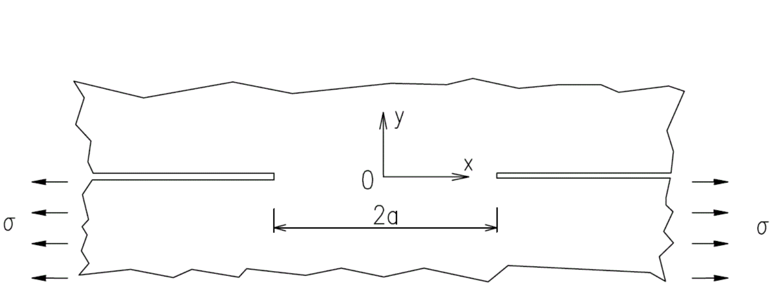

Fig. 3: The double edge-notched infinite plate.

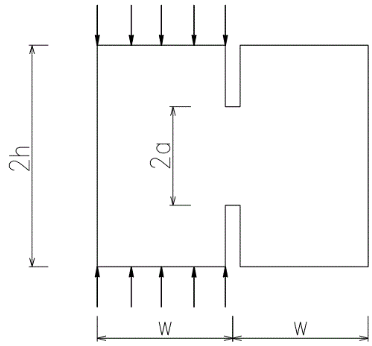

Fig. 4: The double-edge notched specimen.

And from this, the size of the specimen can be determined. It was influenced by two conditions to ensure the theory to go right, if these conditions are not executed the shear crack will not appear because the specimen will not behave as the theory of infinite plate says so, that was described above. These important two formulae are below Eq. (4) and Eq. (5).

$$w \leq \pi a \tag{4}$$

$$2a \leq h \tag{5}$$

The geometry of specimen is shown in Fig. 4 and the shear stress is determined as a stress level when shear cracks along the ligament appear. It is observable in the F-δ curve as a discontinuous zone [1, 3].

Tab. 1: The prescriptions of specimens.

Prescription	Filler [%]	Binder [%]	Binder		Water-Cement ratio
			Cement [%]	Fly ash [%]	
S1	75.0	25.0	50.0	50.0	1.0
S2	75.0	25.0	75.0	25.0	1.0
S3	75.0	25.0	100.0	0.0	0.8

2.4 The Real Test

To prove the theory into the real conditions there were made specimens from cement paste with fly ash. The prescriptions are shown in Tab. 1.

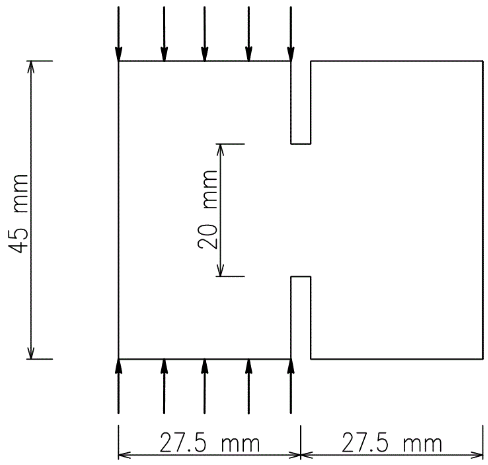

Fig. 5: Size of the testing specimen made from cement paste.

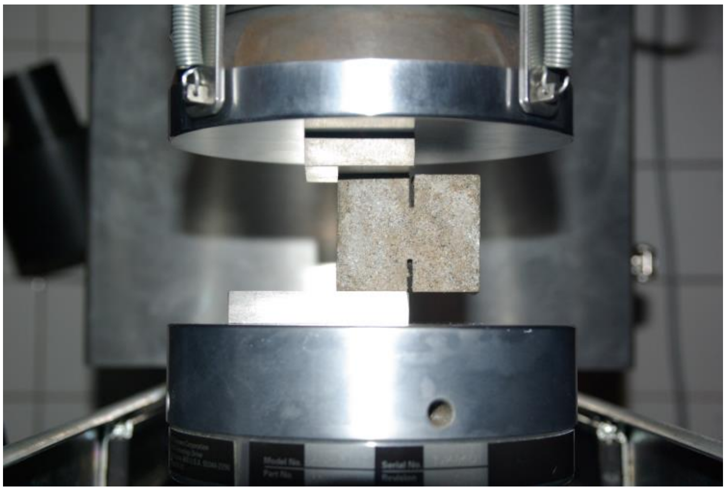

Fig. 6: The specimen in testing device.

The size of the specimen was figured out in consideration of Eq. (4) and Eq. (5). It is shown on Fig. 5. The test was carried on 55 specimens. Specimens were tested in a device for measuring compression strength. It was assumed that using this geometry and loading schema caused the concentration of shear stress along the mouth of the saw-cuts and the shear crack will go along the ligament.

It is needed to mention, that the due to the comprehensive loading on the half of the specimen, the compressive failure will appear. By using the theory of the double-edge notched specimen and executing the Eq. (4) and Eq. (5) the shear failure should appear at first. The load-displacement curve was recorded and the discontinuous zone was noticed, it is shown in Fig. 8. Also the presumed shear crack along the ligament appeared (Fig. 7). But not at all specimens are managed so, it can be seen the Fig. 9, where the factor K_{II} was determined.

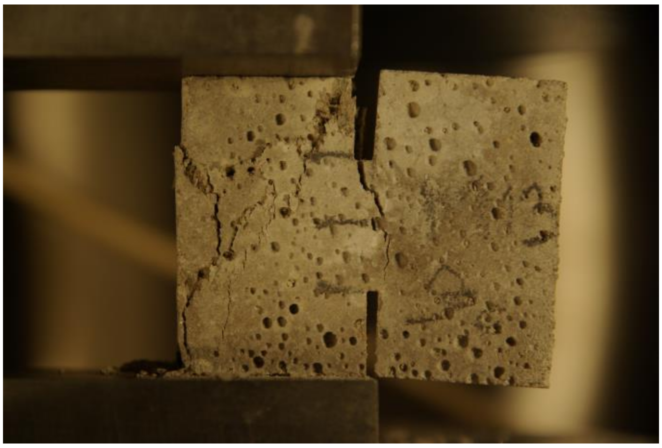

Fig. 7: Size of the testing specimen made from cement paste.

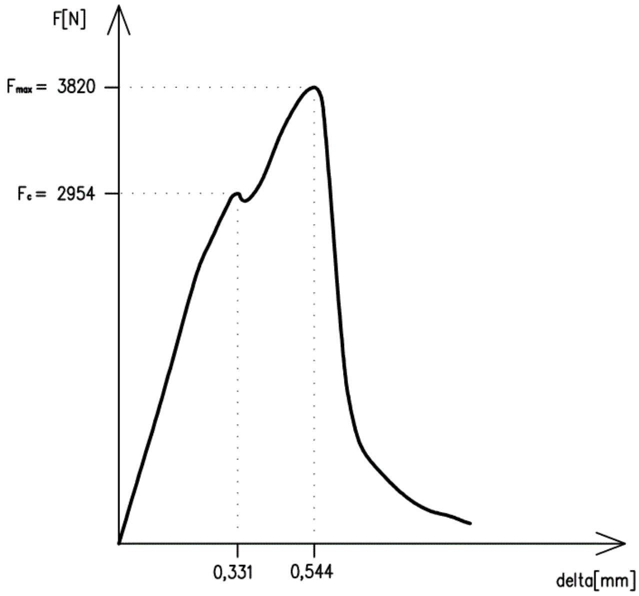

Fig. 8: The specimen in testing device.

3 Conclusion

The aim of this article is to look at the shear stress in the point of brittle mechanic, to test the shear as a mode II failure. In order to understand well the behaviour of concrete and the shear load, mode II testing needs to be performed for measuring mode II fracture toughness $K_{II.}$ There are many methods but none of them gives a result in the pure mode II here.

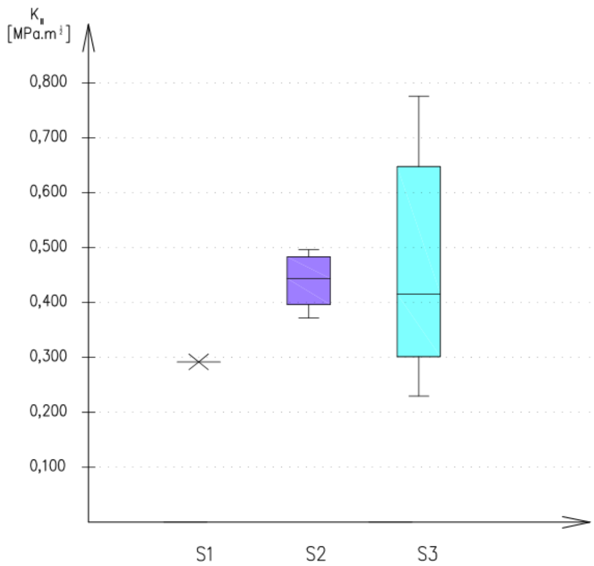

Fig.9: The K_{II} stress intensity factors.

The target of this work is also to try a new geometry and a load configuration so called the double-notched infinite plate, and there were settled conditions for the geometry and formulae for determined K_{II} of a beam based on the theory of the infinite plate in this article. This geometry and loading schema was tested on real beams from cement paste with fly ash.

The assumed shear crack and also the discontinuous zone in the load-displacement curve were observed during the real testing. To summarize, the theory of the double-edge notched specimen was performed into the real test and the antecedent progress was according to the theory of the infinite plate.

Acknowledgement

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References

[1] S. Shah Suredra P., S. Stuart E., O. Chenhsheng, Fracture Mechanics of Concrete, New York, John Wiley and Sons, 1995.

[2] M. Jirasek, J. Zeman, Reshape and Fracture of Materials: Reshape, Plasticity, Demage and Fracture, CTU in Prague, 2006.

[3] S. Xu, H. W. Reinhardt, Shear Fracture on the Basic of Fracture Mechanics, Otto Graf Journal, 2005.

[4] Radaj, D. and S. Zhang, Stress Intensity Factors for Spot Welds Between, Plates of Unequal Thickness, Engineering Fracture Mechanics, 1991.

[5] V Rice, J. R., A Path Independent Integral and the Approximate Analysis of Strain Concentrations by Notches and Cracks, Journal of Applied Mechanics, 1968.