A Numerical Analysis for Concrete Shear test Specimen Geometries.

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Abstract

The main objective of the work carried out in this study was to provide an overall view of the stress distribution in the concrete shear test specimen, together with a detailed study of the area subjected to high shear stresses between the two notches (i.e. the plane between the roots of the two notches. This work could indicate for experimental work to make more understanding on the applicability of this geometry as a concrete shear test specimen.

الخلاصة

ان الهدف الرئيسي من هذا البحث هو لايضاح بشكل عام توزيع الجهود في نموذج القص القص الكونكريتي المراد دراسته وبنفس الوقت دراسة تفصيلية للمنطقة (المساحة) تحت الجهود العالية للقص بين القطوع كمثال السطح.

Introduction

Linear elastic fracture mechanics is the study of stress and displacement field near a crack tip in an isotropic, homogeneous elastic material at onset of rapid, unstable crack propagation, which leads to fracture.

In fracture mechanics, there are three basic modes of crack extension as shown in Fig. 1. The three types of crack extension are as follows [ERDOGAN, F. and SIH, G.C. 1963, BARR, B. 1987], DAVIES 1988].

a) Mode I or crack opening mode which typically occurs in a tensile or flexure test. The crack surface displacements are normal to the crack plane.
b) Mode II or crack sliding mode which typically occurs under shear loading. The crack displacements are in the crack plane and normal to the crack border.
c) Mode III or crack tearing mode which typically occurs under torsional shear loading. The crack surface displacements are in the crack plane and parallel to the crack border

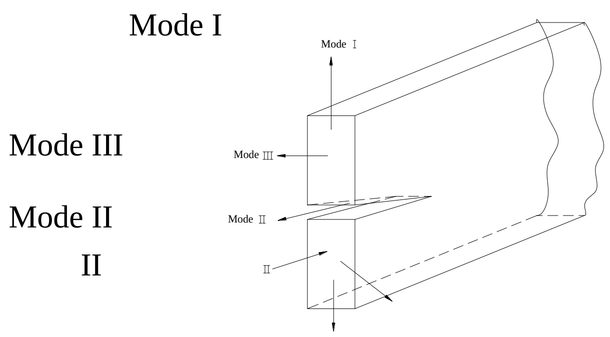

Fig.1 Modes of crack extension.

Most of the early studies concerning the development of fracture tests concentrated on the Mode I type of failure. Fibrous composites are generally weak in shear and hence Mode II and Mode III fracture of composites is an important area of research.

The basic problem in measuring Mode II fracture parameters for any material is the necessity of achieving a pure-shear state of stress and crack propagation with KII >> KI. (where KII and KI are the stress intensity factors in Mode II and Mode I respectively). This means that it is necessary to create a shear force without simultaneous bending and without tensile or compressive normal forces. [SWARTZ *et al* 1988] used a beam specimen in antisymmetric four points bending to study the crack propagation in Mode II. They concluded that this type of beam test does not appear to yield definitive estimate of either KIIC(critical stress intensity factor) or even Mode II crack propagation. However, they observed that the fracture energy values were about eight to ten times of that obtained from Mode I tests (using the same beams and similar procedures).

A variety of Mode II type test specimen geometries have been proposed in recent years. (A full discussion of these test geometries is not included in this study). Examples of Mode II test geometries include those proposed by [Chisholm and Joshes 1977, Arcan *et al* 1978, Leslie-banks *et al* 1983, Watkins 1993, Richard 1981, Barr and Hughes 1988, Bezant and Pfeiffer 1986, Barr *et al* 1987 and Balloteri *et al* 1988].

A comprehensive study of seven test geometrics, which have been used to determine the shear strength of FRC, was reported by [Barr 1987]. This shows that the shear strength in the case of polypropylene fiber reinforced concrete and steel fiber reinforced concrete is relatively independent of fiber content used in the range of 0-1% by volume. In the case of GRC materials the shear strength increases with increasing fiber content.

Reinhardt *et al* 1987 proposed a new testing system which has been designed and built to test plane quadratic push-off type specimens (with an edge length of 200 mm and thickness of 50 mm) under mixed mode loading. They observed that the shear stiffness depends on pre-cracking and shows a reduction with increasing crack opening. These observations were confirmed later by [Nooru-Mohamed and Van Mier 1989] as a result of testing mortar, normal weight and "Lytag" Lightweight high strength concrete, by using double edge notch specimens of the same geometry and method of test as that used by Reinhardt and his colleagues 1987.

Proposed Test Specimen Geometries

The overall test specimen geometry is illustrated in Fig..2. The details of combination of notch depth and slot separation distances are as, (40 mm notch depth and 35 mm slot separation distance, 40 x 40 mm, 45 x 40 mm, 60 x 30 mm and 60 x 50 mm shear plane dimensions). These geometries may be divided into two groups according to their notch depth, Group A with a notch depth less than half width of the specimen with slot separation distances of 35 mm and 40 mm, and group B with a notch depth greater than half the width of specimen and either 30 mm or 50 mm slot separation distances.

The main objective of the work carried out in this study was to provide an overall view of the stress distribution in the test specimen (see Fig. 2), together with a detailed study of the area subjected to high shear stresses between the two notches (i.e. plane CD between the roots of the two notches), A linear elastic finite element analysis was used to assess the influence of geometrical changes in the new test specimen. The limitation of linear elastic FEA was appreciated. However, the results will be used only to determine the general stress distribution in the test specimens.

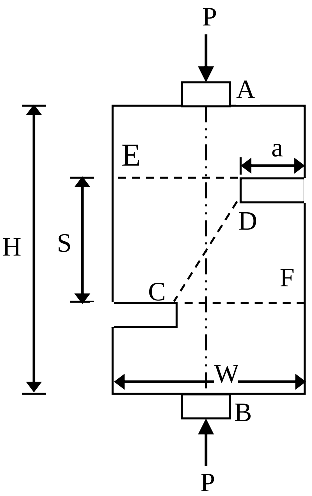

Fig. 2 Specimen Geometry Under Study

The specimens were modeled by using an automatic finite element calculation PAFEC. The [PAFEC] package consists of 10 separate computer programs, which can be executed sequentially to give a complete engineering analysis. Each specimen geometry was represented by a mesh of 220 eight-noded isoparametric elements following a convergence study on one geometry. A typical mesh configuration is shown in Fig.3. The following modes of failure was investigated(see Fig. 4)

(a) Local shear failure starting from point A and propagating towards point D .
(b) Flexural failure starting from point E along the plane ED*
(c) Tensile failure between the notch starting from point G
(d) Shear failure along the plane DC.

Results and discussion

The stress distribution at the roots of the notches and , in particular ,the non-uniformity of these stresses along the line joining these roots are shown in Figs. 5 to 7 . In the first group (Fig 5), increasing the slot separation distance from 35 mm to 40 mm with a notch depth of 40 mm appears not to influence significantly the shear or normal stress intensification at the roots of notches or even along the expected line of failure . Furthermore, increasing the notch depth to 45mm, with a 40mm slot separation distance, only slightly increases the shear and normal stresses near the roots of the notches while their values along the plane between the roots became closer (see fig 5). The normal stresses for the three cases studied were compressive and their values were less than the shear stresses, except near the tip of the notches. However, the specimen geometry with a notch depth of a= 45mm and slot separation of s=40mm shows slightly higher shear stress values near the notch tip. The stress distributions along the plane E-D for this geometry is shown in Fig .5d, which shows that a small amount of tension was developed at the edge of the specimen (at point E).

In the second group, with a 60 mm notch depth and a 30 mm slot separation distance (Fig. 6), there is a significant zone of tension generated towards the mid – height of the proposed failure plane. There is also an increase in the compressive and shear stresses towards the roots of the notches. The numerical analysis shows that the stress at point G is a tensile stress of 3.5 N/mm^2. This value is approximately constant over the plane G-H. On the second plane of possible failure (E-D^*) the stresses are tensile at point E with a value of 2.4 N/mm^2. From the stress distributions shown in

Fig. 6, it is seen that tensile failure could be initiated between the notches, which was experimentally, observed when fracture took place along a vertical line between the notches.

In Fig.7 the notch depth was kept constant (i.e. 60mm) while the slot separation distance was increased from 30 mm (Fig. 6) to 50 mm .The results show that there is an increase in the normal and shear stresses over the notch depth. However, the shear stress increase was less than compressive stress towards the notch root. Furthermore, over the mid –height of the proposed fracture plane C^*- D^* these stresses have similar values. Although there was no tensile stresses developed over the expected plane of failure, the shear stress was slightly higher in this zone than the normal stress and shear failure could not take place over the expected plane of failure between the tip of the notches. The expected plane of failure should be E-D^*due to the high level of tensile stresses adjacent to the point E (see Fig.7b), probably as a result of bending action in this geometry.

The brittle fracture of material under compression is expected to be due to tensile micro stresses. However, the tensile mechanism is not in it self sufficient to cause the failure of the material. Another mechanism most probably controlled by shear stresses, becomes active at some stage of the fracture process. Therefore one can expect that the specimen geometry with 45mm notch depth and 40mm slot separation distance and approximately equal shear and normal stresses fails experimentally by shear since the shearing mechanism could be initiated in zones of high compressive or tensile stress concentration.

Conclusions

1- Before any conclusion can be drawn from the numerical analysis it must be remembered that the analysis was carried out assuming that the concrete material was homogeneous and isotropic, which is in reality not true. Moreover, the effect of coarse aggregate, size and shape of aggregate the percentage of the steel fiber, all have an influence on the failure process.
2- The numerical results for the three geometries with notch depths less than half the width of the specimen and a slot separation of either 35 or 40 mm show that the geometry with 45 mm notch depth and 40 mm slot separation looks more encouraging.
3- Increasing the notch depth so that it is greater than half the width of the specimen with slot separation of less than half width of the specimen (i.e. 50 mm) increases the compressive and shear stresses over the mid-height to approximately the same magnitude and also increases the level of these stresses at the roots of the notches.

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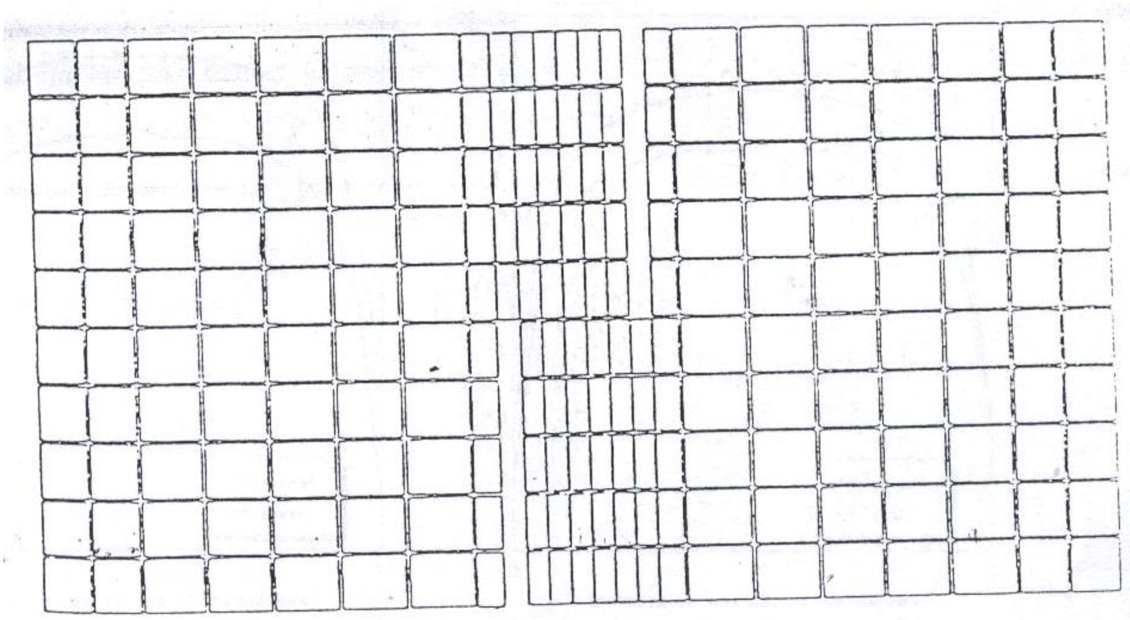


220 Elements

Fig. 3. A typical mesh configuration used in the study

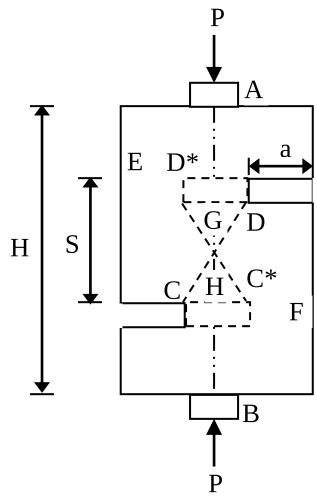
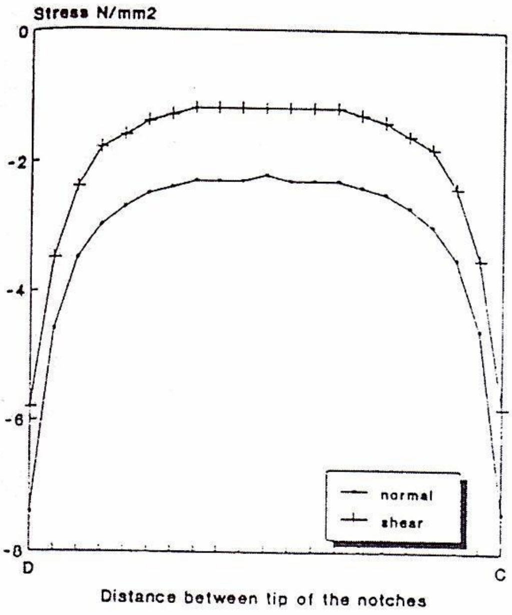
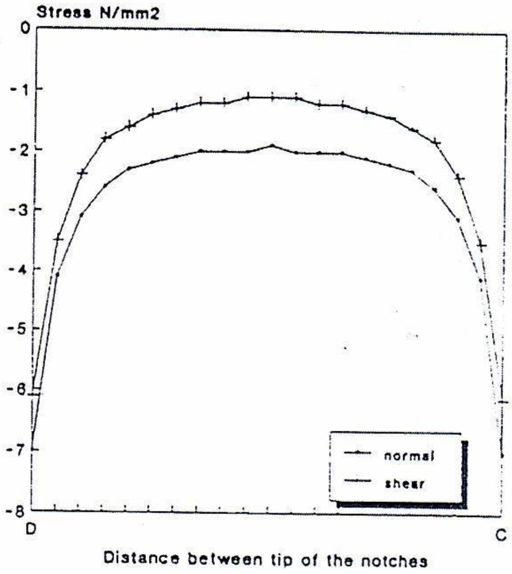


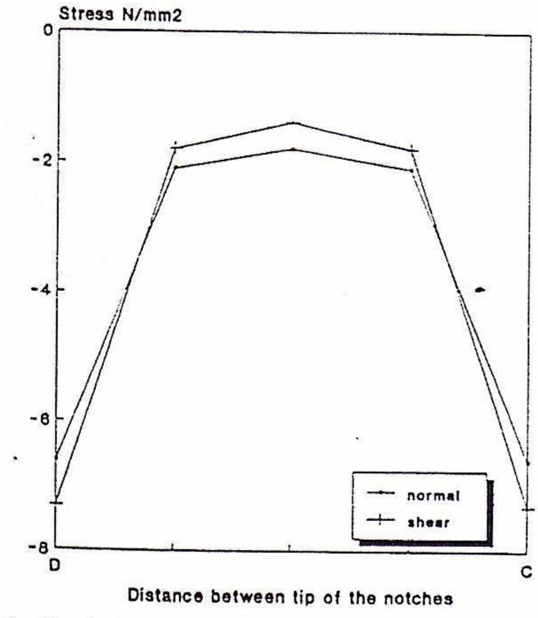
Fig. 4. Shear test specimen showing planes studied



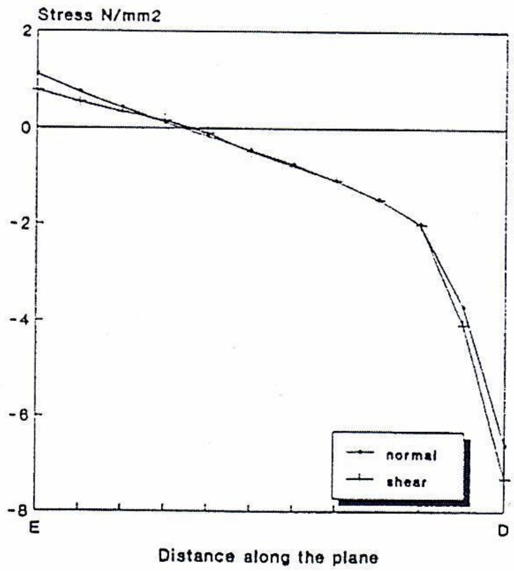
a- Notch depth a=40 mm and slot separation s=35 mm



b- Notch depth a=40 mm and slot separation s=40 mm

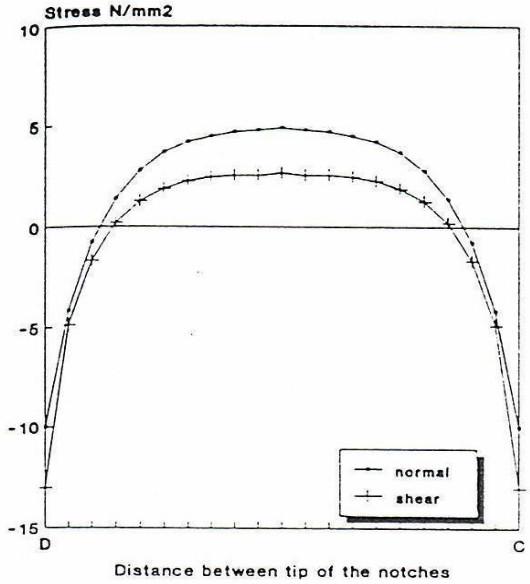


c- Notch depth a=45 mm and slot separation s=40 mm

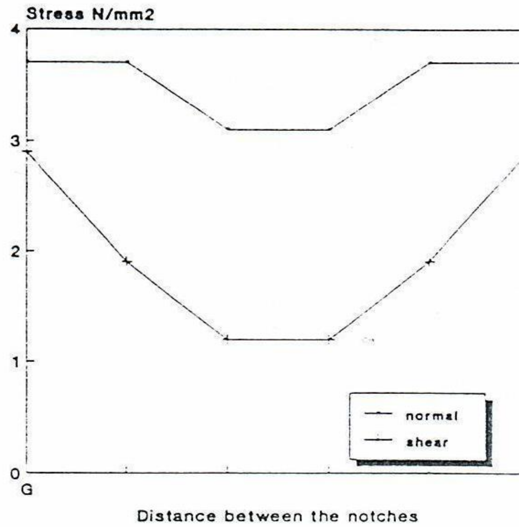


d- Notch depth a=45 mm and slot separation s=40 mm

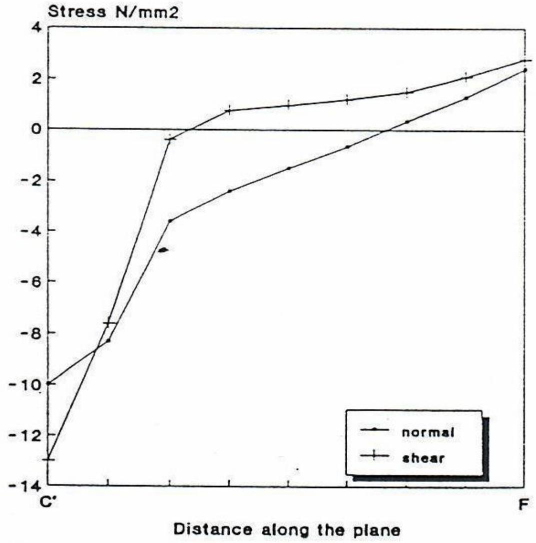
Fig.5 Normal and shear stress distributions



a- Notcn depth a=60 mm and slot
slot separation distance s=40

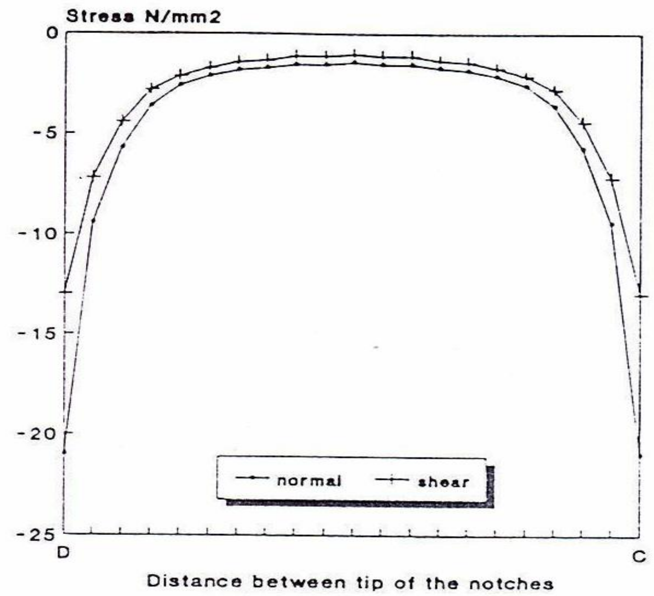


b- Notch depth a= 60 mm and slot
separation s=40 mm
and s=40 mm

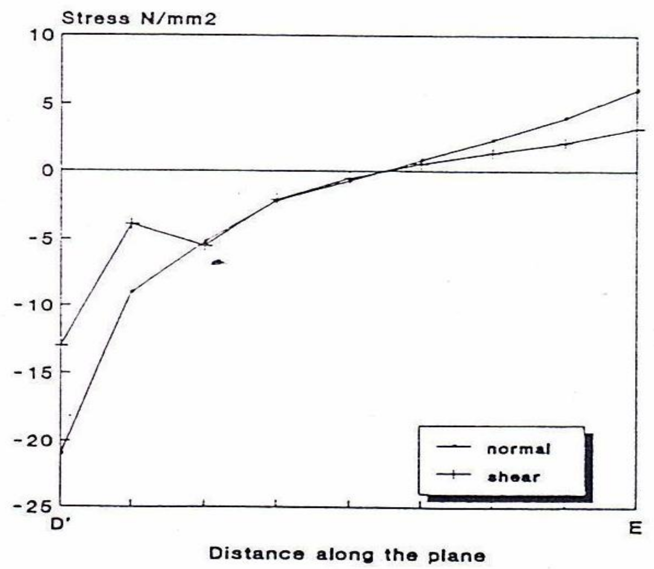


c- Notch depth a=60 mm and slot
separation s=30 mm

Fig.6 Normal and shear stress distributions



a- Notch depth a= 60 mm and slot separation distance s=50 mm



b- Stresses distribution along the plane D'-E of specimen geometry with a=60 and s=50

Fig.7 Normal and shear stress distributions