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S. OKUBO

S. S. PENG

College of Mineral & Energy Resources,
West Virginia University,
Morgantown, West Va.

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Contributed by the Petroleum Division of The American Society of Mechanical Engineers for presentation at the Energy Technology Conference and Exhibit, Houston, Texas, September 18-22, 1977. Manuscript received at ASME Headquarters June 27, 1977.

Copies will be available until June 1, 1978.

ICAN SOCIETY OF MECHANICAL ENGINEERS, UNITED ENGINEERING CENTER, 345 EAST 47th STREET, NEW YORK, N.Y. 10017

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INTRODUCTION

The uniaxial compression test, in which circular cylinders or prisms of rock are compressed parallel to their longitudinal axis, is the oldest and simplest test, and continues to be performed routinely in order to determine the properties of rock including fracture criteria. Unfortunately, the true mode of fracture in uniaxial compression is obscured by several factors (5).[1] Though shear fractures and conical or wedge-shaped fragments are often noticed, these are associated with end-effects. Where some means have been taken to eliminate end-effects, longitudinal splitting has been observed (6).

Though considerable research has been done to deal with the mechanisms of rock fractures (1-3), the mechanism of splitting is not clear. Especially no explanation has been given for the unsteady propagation of splitting which was frequently observed in the laboratory rock testing. In this paper, we tried to explain the unsteady propagation of splitting. The main difference from the previous papers are: (a) we considered the problem in a finite region and (b) we considered the problems when an extended crack is comparatively larger than the initial one.

Attention is called to the occurrence of splitting in specimens of Chelmsford granite subjected to uniaxial compression. Chelmsford granite is a brittle material and contains numerous initial cracks. These cracks significantly affect the strength of the granite and the way the granite fails. Regardless of end-boundary conditions of specimens, cracks in Chelmsford granite propagate parallel to the direction of axial loading. Specimens subjected to end-boundary conditions of steel disk inserts or of neoprene inserts or of teflon inserts fail by longitudinal splitting, parallel to the direction of axial loading. The fracture plane shows the features of tensile brittle fracture. The ultimate strength changes considerably depending on the boundary conditions at the ends of the specimens.

The theoretical investigation was carried out by proposing a model of the splitting fracture. The model contains an inclined crack from which cracks parallel to the axial loading propagate. The stress distribution around the crack was calculated with F E M (Finite Element Method). Assuming a simple criterion of crack propagation, the ultimate compressive strength of a specimen was calculated theoretically. The theoretical result also shows the unsteady propagation of cracks parallel to the loading axis above a certain threshold load. The calculated results are discussed on the basis of the experimental data.

CHARACTERISTICS OF CHELMSFORD GRANITE

Among rocks, granitic rocks are exceedingly brittle. For this reason, we selected the Chelmsford granite to simplify our study of unsteady splitting. Chelmsford granite is quarried by H. E. Fletcher Co. of North Chelmsford, Mass. It is well known that most granites possess three sets of orthogonal directions of splitting. These usually are called rift, grain, and hardway in order of ease of splitting (4).

In Table 1, the physical properties of Chelmsford granite are shown. All of the values are the averages of three directions perpendicular to rift, grain, and hardway, respectively (6). The distribution of crack lengths has been measured. The result is shown in Fig. 1.

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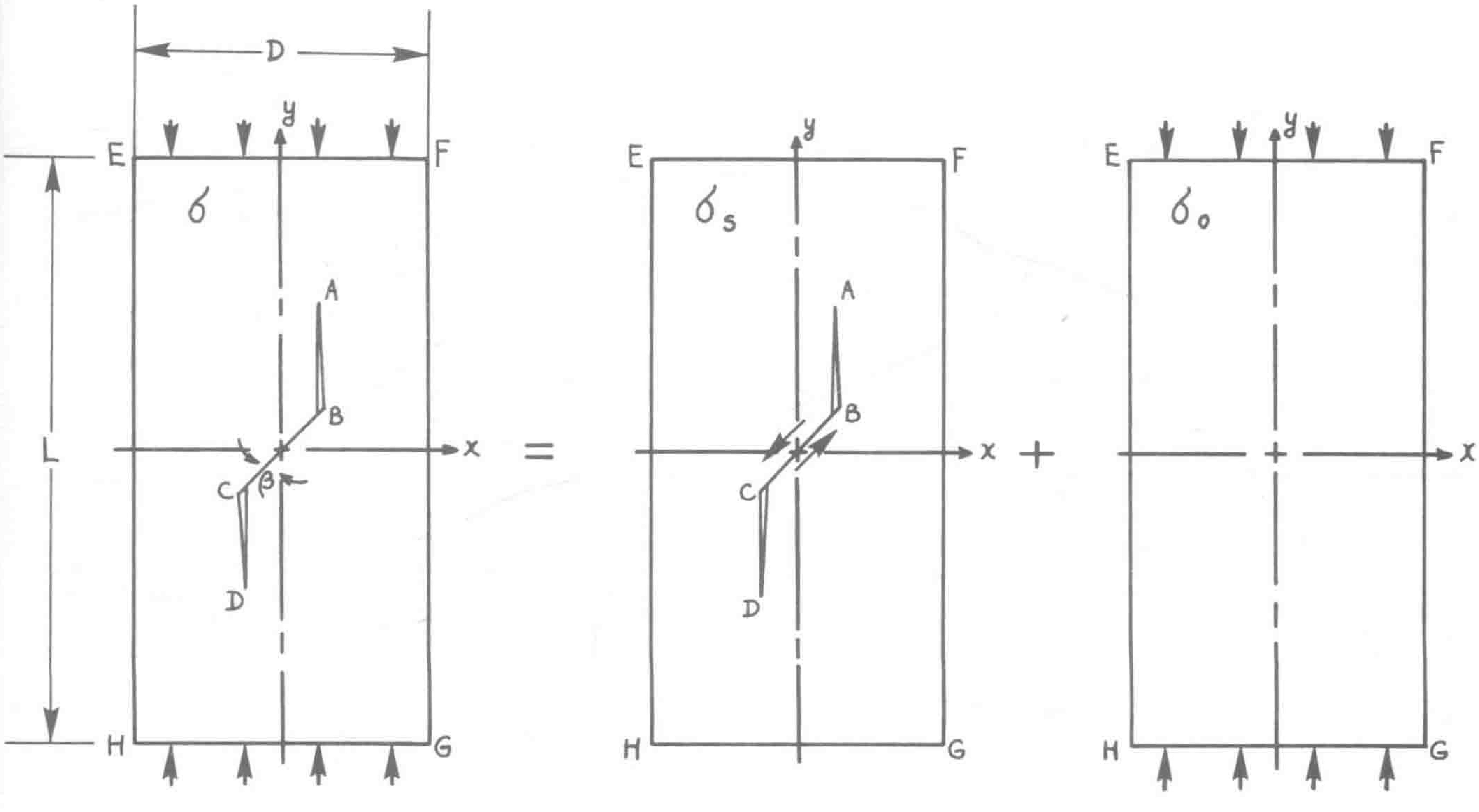
[1] Underlined numbers in parentheses designate References at end of paper.



(a) (b) (c)

Fig. 2 The schematic diagram of a model specimen

$$\begin{aligned} \tau n(S) &= \mathrm{Sin}\beta . \cos\beta \ \sigma_{oy} + \tau sn(S) \\ \sigma n(S) &= \sin^2\beta \ \sigma_{oy} + \sigma sn(S) \end{aligned} \qquad (2)$$

where σsn and τsn are components of $\sigma s(S)$. The slippage along BC begins and the offset, S, increases if the ratio $\tau n(S)/\sigma n(S)$ exceeds the coefficient of friction μ_c on the crack surfaces. It is apparent that the stress level at the tip of the crack increases with increase of offset S. In this analysis, it is assumed that if the least principal stress, σ_p, of the element at the tip of the crack becomes a certain value, σ_c at S = Sc, the crack begins to propagate.

In calculating the least principal stress, σ_p, only the σ_s was considered because σ_o might not contribute to the stress concentration near the crack tip. The critical principal stress, σ_c, which initiates the crack propagation, was assumed to be equal to the least principal stress of the element at the tip of the crack in the plane (Fig. 4) subjected to the tensile stress of To. To is the tensile strength of this material. The finite element mesh around the crack tip was laid out exactly the same as for the previous case where σ_s was obtained (Fig. 2). As discussed before, the condition for the crack propagation is assumed to be

$$\mu_c < \frac{\tau n\ (Sc)}{\sigma n\ (Sc)} \qquad (3)$$

or

$$\sigma_{oy} > c_i = \frac{-\tau sn(Sc) + \mu \sigma sn(Sc)}{1/2\ \mathrm{Sin}2\beta - \mathrm{Sin}^2\beta} \qquad (3')$$

where C_i is the compressive stress when the crack begins to propagate, and σ_{oy} is defined in equation (1) and approximately equal to the average stress on the boundaries, EF and GH.

RESULTS AND DISCUSSION

In the finite element program, the following material constants were used; L = 2 1/2 in., D = 1 1/f in., a = 0.03 in./2, $\nu = 0.11$ and $\beta = 30$ deg, where L and D are the length and width of the specimen, respectively. The initial crack length, 2a, was derived from the value for the distribution function, F = 0.97, in Fig. 1. The inclination of the initial crack, β, was assumed.

Fig. 5 shows the calculated values C_i/To as a function of C, the length of crack propa-

SUPPLEMENT

The effect of the inclination of the initial crack, β , was examined by varying β at 15°, 25°, 30°, 35°, and 45°. At each case the stress, C_i, necessary to make the crack propagate reaches the maximum value at $C = 0.3$. The variation of the maximum value of C_i with the inclination, β , is shown in Fig. 7. The results indicated that the inclination of the most critical crack is 30° as assumed in the paper.

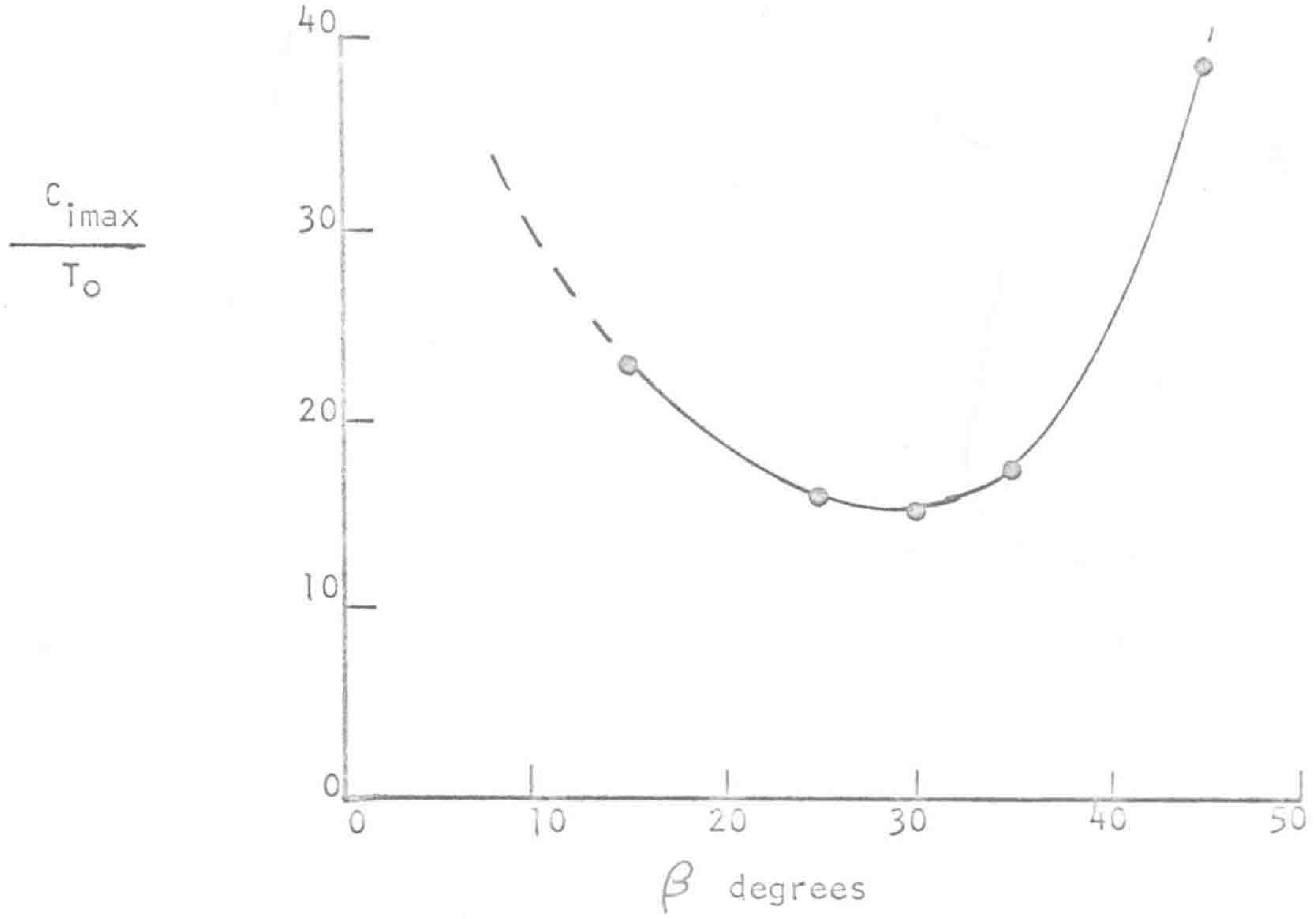


Fig. 7 Variation of the Stress Necessary to Cause an Unsteady Crack Propagation With Inclination of Crack

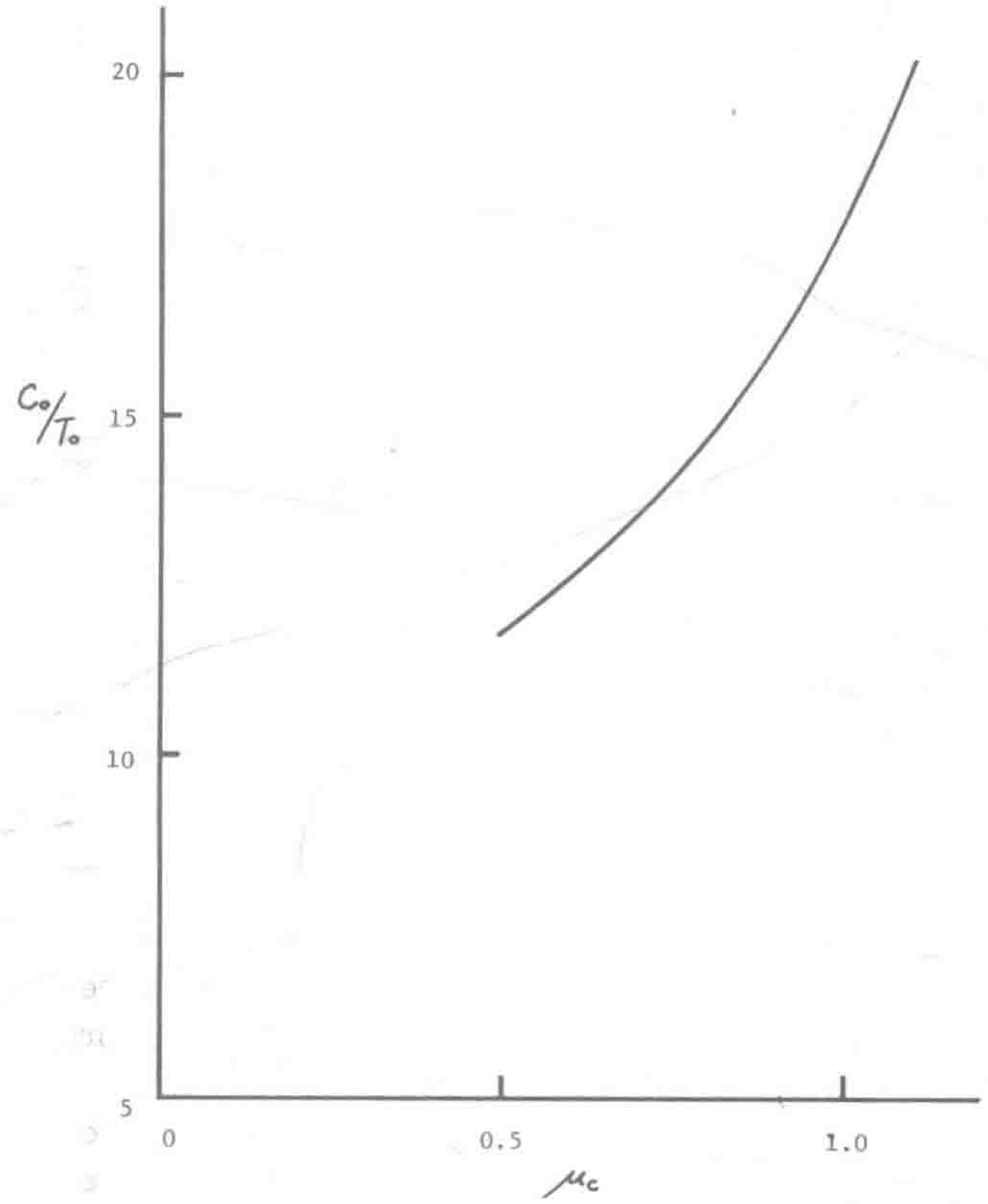


Fig. 6 Variation of the ultimate compressive strength with friction coefficient

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