V-122 SHEAR FRACTURE AND DEFORMATION OF CONCRETE SUBJECTED TO COMBINED EFFECT OF IN-PLANE SHEAR AND NORMAL COMPRESSION

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(1). INTRODUCTION

This paper reports a study of fracture of concrete in a narrow discontinuous zone and its frictional behavior at stable condition, under the combined effect of in-plane shear and normal compression. These data are useful for discrete cracking FEM analysis of concrete.

(2). EXPERIMENT

The test specimen with a square shape shear plane of 100 sq. cm used is in accordance with the push-off specimen as per reference (1). The details of the specimen and loading set-up are as illustrated in Fig.1. On each face of the specimen, slip along the shear plane and separation across it were measured continuously using strain gauge type transducer and pie gauges respectively. Frictional and restraining effects at pie gauges and at various contacts were minimized by using bearings, silicon grease as well as teflon sheets. The variables covered include concrete strength, type of concrete and normal compression level.

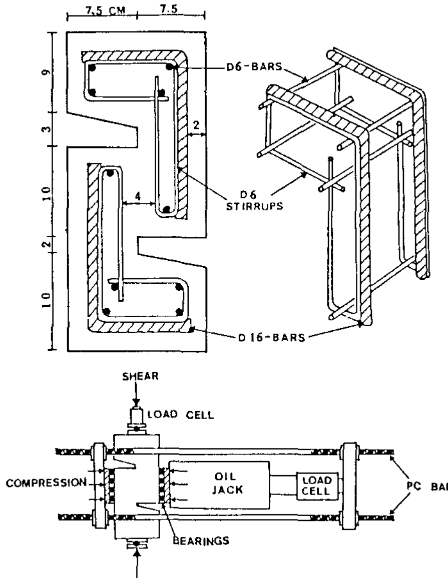

Fig.1 :

Specimen Details and Loading Set-up

(3). RESULTS

Table 1 summarizes the properties and results of the representative 15 specimens used for discussions in this paper. Various criteria have been used in formulating a law of strength under combined states of stress, such as initiation of cracking, yielding and load carrying capacity. The type of specimen and type of test have an appreciable influence on the resulting type of failure. In this investigation, failure is defined as the ultimate load carrying capacity of the test specimen. It is possible to write a failure law in the form $\tau a=(\sigma a)$, the form of which is left to experiment. In this investigation, the experimental data of the specimens can be closely fitted by a linear equation of the form :-

$$\tau a/f'c=A+B(\sigma a/f'c) \quad .....(1)$$

where τa and σa are the nominal shear and nominal normal compressive stresses and $f'c$ is the cylinder compressive strength. By regression analysis, the relationship between nominal shearing and nominal normal compressive stresses at failure was found to be :-

$$\tau a/f'c=0.14+1.37(\sigma a/f'c) \quad ...(2)$$

Material	kg/cm2 $f'c$	kg/cm2 σa	(%) $\sigma a/f'c$	kg/cm2 Vu	(%) $Vu/f'c$
Normal Wt.Normal strength	230	2	0.9	42	18.3
	352	5	1.4	62	17.6
	352	50	14.2	117	33.2
Normal Wt.High strength	545	50	9.2	145	26.6
	545	75	13.8	167	30.6
	675	10	1.5	85	12.6
	675	50	7.4	168	24.9
	675	100	14.8	230	34.1
Light-Weight	330	2	0.6	42	12.7
	330	15	4.5	62	18.8
	330	25	7.6	82	24.8
	321	5	1.6	41	12.7
	321	50	15.6	112	34.9
Mortar	424	6	1.4	69	16.3
	424	64	15.1	143	33.7

Table 1 : Specimen Characteristics

Eq.(2) represents the appearance of the discontinuous zone and good for nominal normal compressive not exceeding 0.20 $f'c$ and holds for all types

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of monolithically cast specimens made of different materials. Fig.2 shows equation (2) with the data. A typical softening behavior of concrete under in-plane shear and normal compression is as shown in Fig.3. At stable condition after softening, the microscopic geometry roughness of shear fracture zone changes insignificantly, and the friction mechanics along the produced crack surface is prominent.

Fig. 4 is a plot showing the change of μ, the mean value of coefficient of friction for various types of specimen tested as a function of normal compression applied. It was found that there is no significant difference in the μ values of all the specimens made of different materials. It was also found out that the magnitude of normal compression applied during shear fracture formation, σu, does not produce significant change in μ with the exception of mortar specimen whose μ values are lower with higher compression applied during shear plane formation. That is to say μ can be taken as independent of the initial characteristic of the shear fracture plane as illustrated by the representative Fig.5 . In any case, all their μ values decreases with the increase in the normal compression after fracturing. Values of μ found are as tabulated in Table 2 below:-

kg/cm2	$\sigma a=0$	$0<\sigma a\leq 20$	$20<\sigma a\leq 50$	$\sigma a>50$
μ	1.6	1.4	1.2	1.0

Table 2 : Values of μ

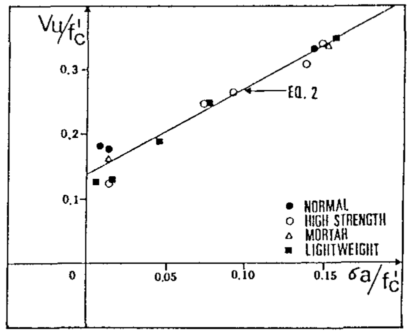

Fig.2 : Failure Envelope

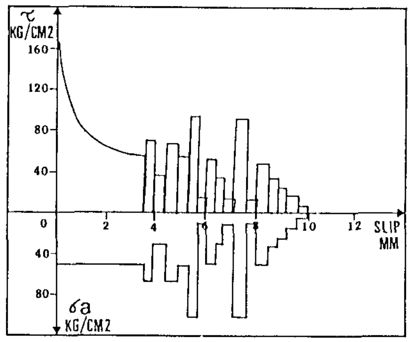

Fig.3 : Typical Softening Curve

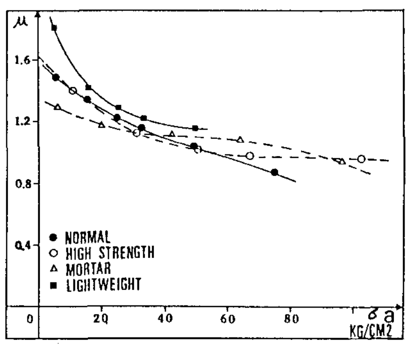

Fig.4 : μ vs. σa

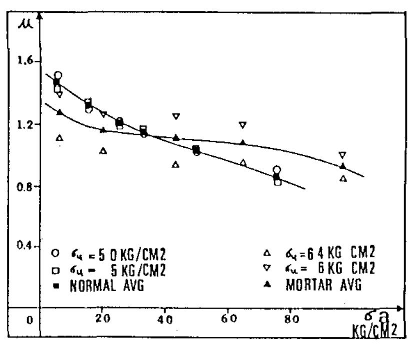

Fig.5 : Effect Of σ_u At Fracture On μ

(4). CONCLUSIONS

The failure criterion of plain concrete under in-plane shear and normal compression can be predicted using a linear equation as shown above and holds good for normal weight concrete, lightweight concrete and mortar. The values of coefficient of friction have been found to be a function of normal compression in the stable portion of softening curve. Furthermore, μ of concrete is independent of the initial characteristics of the fracture surface formed by different magnitude of applied compression at ultimate shear. However, μ of mortar specimen is lower with higher compression applied during fracture surface formation.

(6). REFERENCE

(1). "Method of Test for Visible Shearing Strength of Concrete under Shearing and compressive Loads," Concrete Journal of JCI Vol.23, No.3, March 1985, pp.25-26.