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FRICTIONAL STRESS TRANSFER MODEL FOR CONCRETE CRACKS IN THE CRACK CLOSING AND OPENING WITH SHEAR SLIP MODES

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1. INTRODUCTION.

The so-called "Contact Density Model" developed by B. Li and K. Maekawa[1] can well be applied to predict stress transfer through concrete cracks in monotonic, non-monotonic and reversed cyclic loading paths, all of which are constant crack width loading paths. However, the model fails to match real behavior of stress transfer in crack deformations involving crack closing and opening with shear slip as reported in [2]. This paper introduces modifications of the model to be applicable to the mentioned mixed modes of crack deformation.

2. MODIFICATIONS OF THE ORIGINAL CONTACT DENSITY MODEL.

The original contact density model does not take into account effect of friction along constituent planes of a crack surface. Thus, it failed to predict stress transfer responses in loading paths in which there is much effect of the friction [2]. We have proposed two concepts concerning frictional effect to modify the model.

1. Quantitative definition for Deformational and Frictional Planes.

As mentioned in [2], local deformation of a constituent plane consists of plane deformation and frictional slip. We need quantitative definition for deformation and frictional plane in order to quantify the combination of plane deformation and frictional slip in any constitutive plane and for any loading path. Let us consider a plane θ subjected to an infinitesimal deformation $d\omega c$ in normal direction and $d\delta c$ in tangential direction as shown in Fig 1. Frictional plane factor Kf is defined as

$$Kf = g\left(\frac{d\omega c}{d\delta c}\right) \tag{1}$$

where

$\frac{d\omega c}{d\delta c}$ is defined as " deformation ratio "

We assume Kf to be 1 when the deformation ratio is 0 which means that the companion planes relatively move along the tangential direction and the plane is a perfect frictional plane. A plane will be a perfect deformational plane if there is a deformation in perpendicular direction and Kf will be assumed as 0. Kf is between 1 and 0 when companion planes move between the two extremes and the plane will be a combination of frictional and deformational plane [Fig 1].

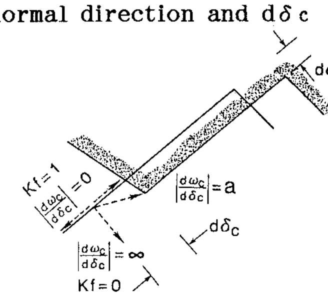

Fig 1

We propose a simple function for Kf [Fig 2]. When the deformation ratio is more than a value, say, "a"[Fig 1,2] Kf is 0 or the plane is a perfect deformational plane. If the deformation ratio is less than the value "a", Kf is assumed as 1 and the plane is a perfect frictional plane.

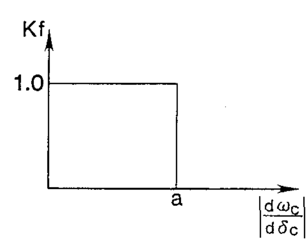

Fig 2

Here, we introduce a parameter δe or "effective frictional slip" which will be an important parameter governing frictional behavior on a frictional plane and is defined as

$$\delta e = Kf \cdot \delta f \tag{2}$$

δf is "apparent frictional slip" which can be computed from a deformational path[2].

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2. Path Dependent Frictional Model.

Firstly, we should consider the role of friction on an individual constitutive plane. Friction acts as a medium to transfer tangential force along the plane. Fig 3 is an enlarged diagram of the plane on a crack surface. The diagram shows that this plane is subjected to a contact compressive stress σ_c and a contact shear stress τ_c with friction at the junction of the planes. The $\mu\sigma_c$ is frictional capacity at the time and if τ_c is less than this frictional capacity, the plane will deform elastically [Fig 3a]. If τ_c equals the frictional capacity, there will be a dynamic slip on the plane in addition to
the elastic deformation[Fig 3b].

How the contact shear stress is transferred is governed by a path dependent frictional model [Fig 4]. In the figure, Gs is stiffness along tangential direction on a constitutive plane. The frictional capacity $\mu\sigma_c$ changes accordingly when there is a change in contact compressive stress σ_c and the contact shear stress τ_c can not be greater than the frictional capacity.

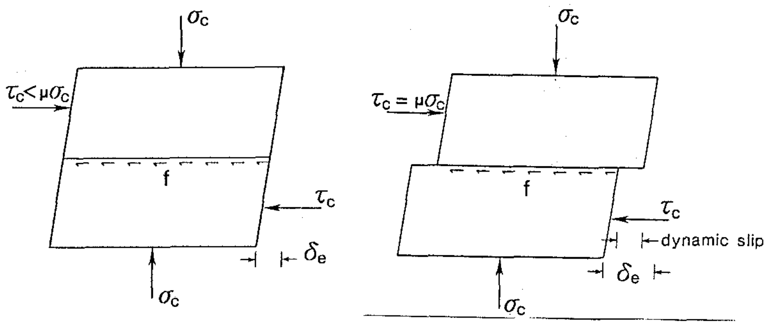


Fig 3

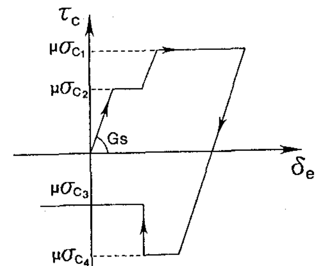


Fig 4

3. COMPARATIVE ANALYTICAL RESULTS.

By incorporating the two concepts concerning frictional effects into the original contact density model, a modified model can be obtained. Fig 5 compares analytical results from the original model and the modified one with experimental results. It can be clearly seen that the modified model is better applicable than the original model.

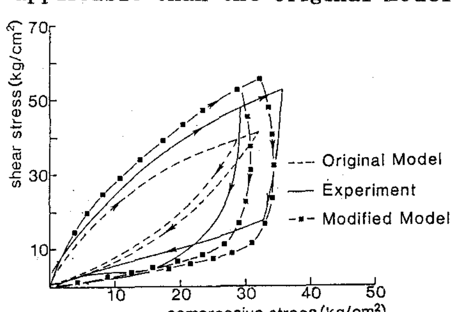
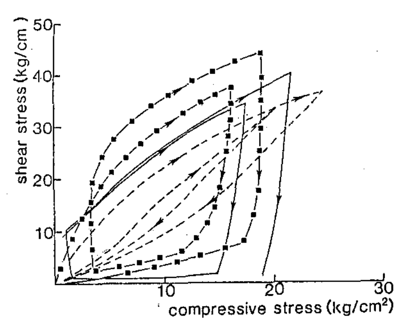


Fig 5



4. CONCLUSION.

The modified model with more applicability could be attained by appropriately including the frictional effect into the original contact density model. However, more experiments are needed to better verify the Kf function and the path dependent frictional model.

REFERENCES.

[1] B. Li, K. Maekawa and H. Okamura, Shear Transfer of Cracked Concrete Under Cyclic Loading, Journal of The Faculty of Engineering, The University of Tokyo, Volume XXXXVI No.2 (1988).

[2] BUJADHAM Buja, LI Baolu, MAEKAWA Koichi: "Stress Transfer Model for Concrete Cracks in the Crack Closing and Opening with Shear Slip Modes.: Proceeding of the Second East Asia-Pacific Conference on Structural Engineering and Construction, January, 1989.