

# Study on the Combined Performance of Fiber Reinforce Concrete Material

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**Abstract:** As concrete is a heterogeneous material. There is a combination of weak interface – interface in the concrete. From the point of view of mechanics analysis, the interface exists in the combination of materials within the boundary [1]. For ordinary concrete, damage often occurs from the junction interface. The analysis of concrete materials and its stress distribution near the interface has vital significance. In fact, the boundary condition on the interface, and mutual constraint represent the deformation of the fiber and concrete. The constraints cause stress concentration of interface and nearby interface geometry mutations where stress concentration is very serious. In the elastic range, the stress point at some point tends to infinity, called a singularity. At the same time, due to material composition by multiphase materials, there are a lot of micro cracks at the interfaces. The study of the interface crack model and the materials of the singularity has an important means for the material's performance.

**Keywords:** Concrete, crack, earthquake, fiber.

## 1. INTRODUCTION

Concrete is suitable for bridge decks, thin shell structures, nuclear power plants and defensive facilities that may experience impact loads such as earthquake and blast loading. But the higher the strength of the concrete, the more brittle it is [1-3]. Understanding the strain rate effect is very important in assessing the structural capacity in resisting impact and blast loads. It is well known that using small amount of steel fibers into concrete will enhance the tensile and fatigue resistance and toughness of concrete. Although the mechanical properties of steel fiber reinforced concrete have been investigated intensively, and widely used in engineering, most of these investigations and applications were only limited to the static and dynamic case [4-6]. The study on the combined performance of fiber reinforce concrete material had not been carried out. In this paper, combined performance of fiber reinforce concrete is studied. Pointer to the combined performance is obtained.

### 1.1. Dundur Parameters

For composite materials such as fiber reinforced concrete, there are two important combinations of elastic parameters - Dundurs parameters:

$$\alpha = \frac{\mu_1(k_2 + 1) - \mu_2(k_1 + 1)}{\mu_1(k_2 + 1) + \mu_2(k_1 + 1)} \quad (1)$$

$$\beta = \frac{\mu_1(k_2 - 1) - \mu_2(k_1 - 1)}{\mu_1(k_2 - 1) + \mu_2(k_1 - 1)} \quad (2)$$

Where  $\mu = \frac{E}{2(1+\nu)}$ ;  $k = \frac{3-\nu}{1+\nu}$  in the plane stress problem,  $k = 3-4\nu$  in the plane strain problem,  $\mu = \frac{E}{2(1+\nu)}$ ,  $\nu$  is the Poisson's ratio.

The Goursat equations are:

$$\sigma_y + it_{xy} = \xi' + \bar{\xi}' + z\zeta'' + \zeta' \quad (3)$$

$$\sigma_y - it_{xy} = \xi' + \bar{\xi}' - z\zeta'' - \zeta' \quad (4)$$

$$2\mu(\mu + i\nu) = k\xi - z\xi' - \bar{\zeta} \quad (5)$$

According to the Dundurs solutions, we can obtain the following equations:

$$\xi_1 = \frac{1+\beta}{1-\alpha}\xi_2 + \frac{\beta-\alpha}{1-\alpha}(z\xi_2' + \bar{\zeta}_2) \quad (6)$$

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$$z\bar{\xi}_1 + \bar{\zeta}_1 = -\frac{1+\beta}{1-\alpha}\bar{\xi}_2 + \frac{\beta-\alpha}{1-\alpha}(z\bar{\xi}_2 + \bar{\zeta}_2) \quad (7)$$

Dundur parameter actually gives the interface constraints of the composite material and the influence of material properties. Concrete is a kind of composite materials, substrate material and aggregate in concrete interface. The fiber and matrix material interface is a weak link, taking the Dundur parameters into consideration for the fiber reinforced concrete which is the foundation for singularity characteristics at the interface of the fiber reinforced concrete [2].

**1.2. Fiber Enhanced Model of Concrete Material**

Studying the micro cracks in the concrete material model, in fact, the focus on the research is singular in the interface crack. However, the role of adding fiber concrete is mainly a strengthening and toughening effect. It is necessary to study the role of fiber in the substrate concrete.

There are some models can be used to study the combined performance of fiber reinforce concrete.

**Model 1:**

Research problems of single fiber based mechanical model are shown in Fig. (1), with cracks and fiber in total plus under the action of stress field. To simplify, only plane strain or strain is considered. This paper only considers I type crack problem. We assume that an absence of fiber plus I type caused by stress field in crack tip stress intensity factor for K0. Due to the role of the fiber, near crack tip

stress intensity factor of the change, K1 is used.  $\Delta K = K_1 - K_0$  can be used to describe the toughness role of the fiber . If  $\Delta K < 0$ , fiber on the crack tip field is shielded (toughness).

For this crack in the substrate material in the model [8], we can obtain:

$$\Delta K = \frac{K_0}{\pi} \int_A r^{-2} (C_1 \cos \frac{\theta}{2} \cos \frac{3\theta}{2} + C_2 \cos \theta \sin^2 \theta) dA \quad (8)$$

Where

$$C_1 = \frac{(1-\alpha)(1-2\mu)}{1+\alpha-2\mu}$$

$$C_2 = \frac{3(1-\alpha)}{2(1+3\alpha-4\mu\alpha)}$$

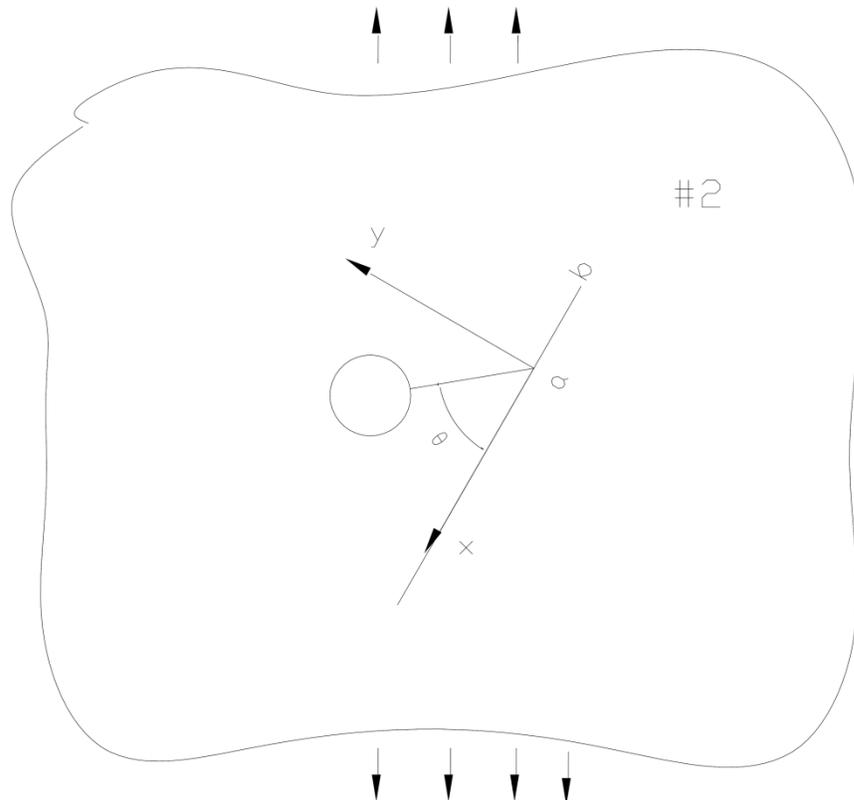
$$\alpha = \frac{E_x}{E_h}$$

Among them,  $E_x$  is for the elastic modulus of fiber, and  $E_h$  is for concrete elastic modulus of matrix.

**Model 2:**

Research problems of fiber based mechanical model are shown in Fig. (2). At this point, the crack and fiber are still under the action of stress ( $\sigma_0$ ) field. To simplify, only plane strain or strain problem is considered.

For solving the conversion (Fig. (2b)) of the three layer



**Fig. (1).** Single fiber based crack model of concrete.

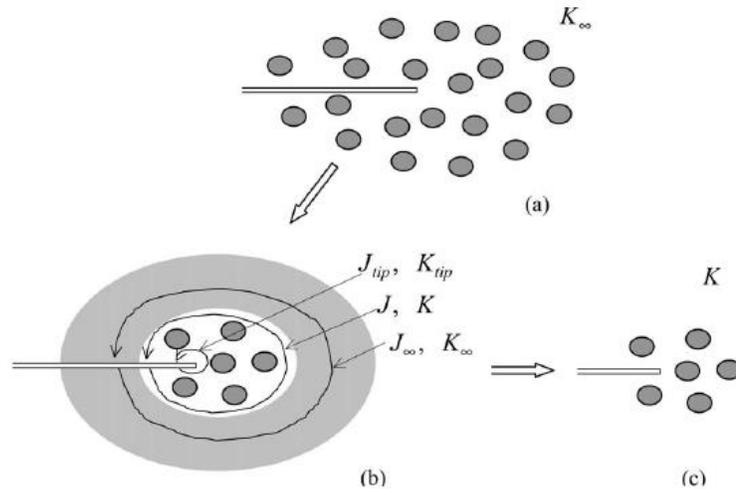


Fig. (2). Much fiber based crack model of concrete.

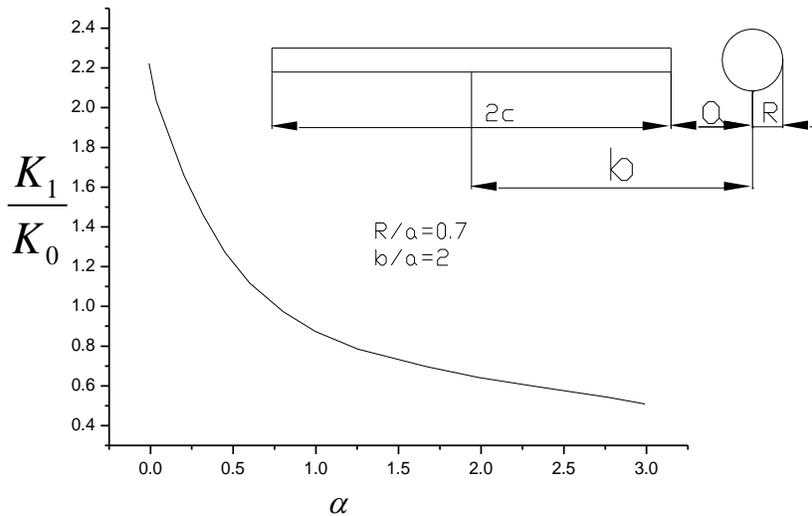


Fig. (3). The relationship between the  $\frac{K_1}{K_0}$  and  $\alpha$ .

model), the first layer is of fiber, the second is the concrete substrate, and the third layer is of fiber composite concrete materials. We thus obtain:

$$\frac{K_1}{K_0} = \sqrt{\alpha_2} \left[ 1 + \frac{1}{\pi} \int_A r^{-2} (C_1 \cos \frac{\theta}{2} \cos \frac{3\theta}{2} + C_2 \cos \theta \sin^2 \theta) dA \right] \quad (9)$$

Defining  $\alpha_2$  as the ratio of the elastic modulus between the concrete matrix and the fiber. For single fiber, it can be thought that the second and third layer materials are consistent. Then eq.2 degradation for eq.1 is:

So in specific conditions, we can solve the eq.1 with numerical calculation. The relationship between the  $\frac{K_1}{K_0}$  and

$\alpha$  can be obtained and we can discuss the behavior of the strengthening and toughening effect. With reference to the

literature, the specific parameters and the relation curves are all obtained (Fig. 3).

2. CONCLUSION

Eq.1 describes the role of toughening for single fiber. Much fiber based crack model of concrete is also given in this paper. The single model of toughening pointer can be obtained from the much fiber based crack model. In the distance close to the fiber, toughening effect is good.

2 From Fig. (3), we can see that steel fiber and other hard fiber can join the hard substrate material (concrete grade is high) in the concrete, and soft fibers such as polypropylene fiber can generally add soft substrate material in the concrete (concrete grade is low).

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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