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Crack Resistance and Strength of Hybrid Fiber Reinforced Concrete using the Macro and Micro Steel Fibers

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ABSTRACT

Hybrid fiber reinforcement with both macro and micro steel fibers in the concrete matrix is applied in order to evaluate its effectiveness for crack arresting. One of the main objectives of this research is to establish a crack-free high performance concrete. In severe conditions, which may require high water tightness, such as a storage structure for low-level radioactive waste, crack-free high performance concrete structures could be applied. Hybrid fiber reinforcement is well known because it can show excellent performance with a suitable combination of fibers. In this study which deals with hybrid fiber reinforced concrete made with different fiber lengths and fiber contents, the factors which quantify crack resistance of concrete, mainly the first crack strength, flexural strength and strain energy release rate are examined.

1. INTRODUCTION

Cracks occurring in concrete structures was be due to 1)micro flaws between the cement matrix and aggregate, 2)micro cracks caused by drying shrinkage or 3)macro cracks due to the applied load. Concrete eventually fail due to the propagation of cracks (Fujita et al., 1978). For industrial waste disposal facilities and storage structures for low level radioactive wastes, a low permeability and highly watertight concrete is required. It is therefore essential to control the micro cracks both at early ages and also in the long term. The aim of this research is to examine the crack resistance of hybrid fiber reinforced concrete using a combination of macro-steel fibers and micro-steel fibers.

Usually, the tensile strength of concrete (as induced for thermal stresses in mass concrete) is used to estimate the crack resistance. However, in this research, from the viewpoint of fracture mechanics, the crack resistance was estimated by the strain energy release rate, using the elastic modulus to determine the deformation behavior as well as the tensile strength. Since the 1970`s, fiber reinforced concrete(FRC) has been widely used in construction for the improvement of the flexural and tensile strengths of concrete (Batson, et al., 1973). Usually, the name FRC implies concrete

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reinforced with only one kind of fiber (e.g. steel fibers, glass fibers, carbon fibers) Recently, hybrid fiber reinforced concrete(HFRC), i.e., fiber concrete using 2 kinds of fibers has attracted special attention (Horiguchi et al., 1997 ; Rossi et al., 1997). One of the advantages of hybrid fiber reinforcement is that reinforcing effects can be obtained by a suitable combination of fibers (Kim et al., 1998 ; Banthia et al., 1996).

This research, was aimed at the improvement of concrete durability concerned with regard to water-tightness by the control of first crack initiation (cracks initiated at early stages under loading), by the addition of a combination of macro and micro steel fibers (Mihashi et al., 1999 ; Murakami et al., 1995). The effects of different contribution of fibers of different lengths on the strength and strain energy release rate are discussed (Mihashi et al., 1997 ; JSCE, 1997).

2. EXPERIMENTAL OUTLINES

2.1 Experimental plan

In this research, to compare the reinforcing effects of macro and micro fibers their combinations (that is hybrid FRC), 3 series of specimens were made. These are 1) SF-30, reinforced by 30 mm macro steel fibers(FRC), 2) SF-6, reinforced by 6 mm micro steel fibers(FRC), and 3) SF30-SF6, reinforced by a combination of macro and micro steel fibers(HFRC) (Kim et al., 1998 ; Kim et al., 1998).

For the macro-fiber FRC's, the fiber contents were ranged from 0.0% to 2.0%. For the micro-fiber FRC's, the fiber contents ranged from 0.1% to 2.0%. For the HFRC, a numbers of combination of fiber were, during total fiber contents increase 1.0% to 3.0%. As seen in Table 1, 18 series of specimens (including one of plain concrete) were produced in total.

The cement type was ordinary portland cement(OPC). River sand and crushed stones were used. Also, for obtaining the workability of HFRC, by the use of superplasticizer, the slump was maintained at 10±2cm, and the air was controlled by 5%. A polycarbonic acid superplasticizer was used, and the amount used was below 1.3% of cement weight.

The aspect ratio(l/d) is 60 for the macro and micro steel fibers each. The characteristics of fibers and materials used in this research are shown in Table 2 and Table 3, respectively.

2.2 Experimental plan

A static 4-point bending test was conducted using beam specimens of 100×100×400mm on a span of 300mm. The load was applied continuously at a rate of 0.2mm/min. By using a linear variable displacement transducer (LVDT), the deflection was measured at the center of the specimen. Also, the crack mouth opening displacement (CMOD) was measured at the center edge of specimen with notch (depth/specimen height = 0.3) by using a clip-gauge.

The first crack and the strain energy release rates were obtained from the load deflection curves of the 4-point bending test results. The dimensions of specimen and the experimental apparatus used in this research is shown in Fig.1.