Investigation on Structural Performance of RC Beams with Crack Mouth Opening Displacement: A Review

Etaveni Madhavi, P. Poluraju

Abstract:--- Concrete is a composite material which is used more and also utilization is becoming more and more because it has high compressive strength and low cost. The concrete member cannot with stand the more tensile, as it is a compression member and also it is brittle material. The durability will be depending on the cracks, if the crack width is developing more than the durability will affected. To know the crack width and to understand the crack formation in concrete. The crack width can be estimated as crack mouth opening displacement. Several optical and non-optical methods can provide information about crack presence but do not provide information on crack opening and crack width which are important from considerations of durability. Crack mouth opening displacement (CMOD) is an important parameter that is used in characterization of fracture. The crack mouth opening displacement has been measured during fracture tests of concrete beams.

Index Terms: Crack mouth opening displacement, Crack tip opening displacement, Failure modes, Fracture energy

I. INTRODUCTION

Concrete is most versatile material used in construction [6]. The concrete is the composite material which allows to get cracks, which cannot controlled. The structural failure occurs due to the loads imminent on structure, materials efficiency etc. The loads may occur in form of static loads or dynamic loads. The static load or stationary load is due to self-weight of structure or the loads that a structure is carrying. Dynamic load is a load produced by wind or seismic activity. By opposing to these entire loads, the structures had to be designed. Crack tip opening displacement (CTOD) is only a way to check the cracks which are occurring, where as the fracture extension also will is calculated. The fractures are assumed to occur when the crack opening displacement exceeds a critical value. The failure of a structure can be seen in 2 ways

- Crack Initiation: Due to high concentration of stresses, small cracks develop at some point.
- Crack Propagation: Advancement of stress concentration leads to increment of cracks.

One of the important parameter is crack tip opening displacement which is used to characterize the fracture in engineering materials. As we found difficult to determine crack tip opening displacement, measuring of crack mouth opening displacement is implemented for fracture tests of concrete beams.

Process of fatigue has been shown in Fig. 1.

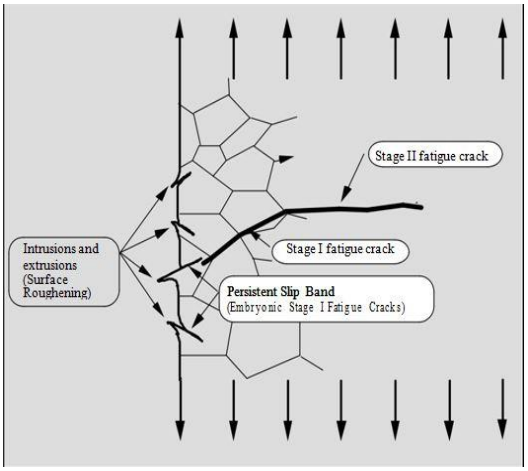

Fig. 1: Process of fatigue

Micro-crack is one of the characters of concrete in the fractures. Due to the micro cracks the non linear stress-strain response, post peak soft point are increases the fracture toughness.

The existence of micro-cracks and inherent flaws in a structure may lead to fracture under extreme loading. A Fracture is defined as “Separation of object in two parts under the action of high stress”. The Fracture of a structure can be classified as Brittle Fracture and Ductile Fracture. In Brittle fracture displacement cannot be observed, directly it gets separated where as in ductile fracture displacement of an object can be observed before it gets separated.

II. FRACTURE MECHNICES OF CONCRETE STRUCTURES.

To investigate the behaviour of concrete according to fracture mechanics. Fracture parameters of cementitious materials under stress have to be determined by area under load-deflection curve. Fracture mechanics classified into:

a. Linear elastic Fracture mechanics(LEFM)
b. Elastic plastic Fracture mechanics(EPFM)
c. Dynamic Fracture mechanics(DFM)

a. Linear elastic fracture mechanics (LEFM)

In the LEFM the material will be isotropic and linear elastic material. The theory of elasticity is used to calculate the stress near the crack. Depending up on the stresses which are available at the crack tip the fracture and crack changes will occurs. When the stresses are increased the crack with also increases.

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Stress concentration at the tip of crack will be greater and calculated using the theory of elasticity. The effect of higher at the crack tip engenders the crack to grow. LEFM will be precise only when the plastic deformation is insignifact compared to the size of the crack.

b. Elastic plastic Fracture mechanics (EPFM)

In the Elastic plastic Fracture mechanics, the material is isotropic and elastic plastic material. By Taking this in to account this assumptionis the stress concentration and the strain energy fields and displacements are at crack tip is calculated. In case if the plastic deformation develops before the crack grow then EPFM is relevant

c. Dynamic Fracture mechanics (DFM)

Examined under dynamic and shock load.The above Fracture mechanics are considered for determining the fracture parameters of any structural elements.

III. MODES OF FAILURE

The concetration of stress at the crack tip is wider and the relative movement of crack surface for an elastic material were concentrated by Irwin. The Fracture modes can be classified as:

- Mode-1 : Opening Mode
- Mode-2 : Sliding Mode
- Mode-3 : Tearing Mode

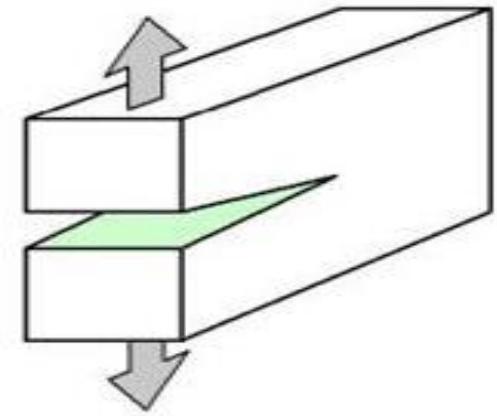

Fig. 2: Opening Mode

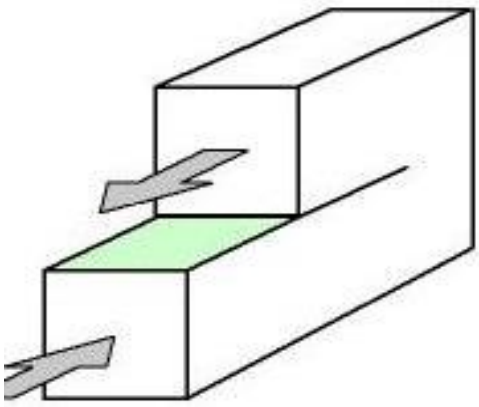

Fig. 3: Sliding Mode

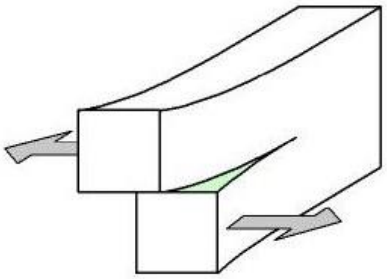

Fig. 4: Tearing Mode

The above figures show the failure modes.

Fig. 1: Opening mode is also called as tensile mode i.e., displacement of crack surfaces is perpendicular to the plane of crack. It is most dangerous and can be noticed easily under tensile loading.

Fig. 2: Sliding mode is also called as shearing mode i.e., displacement of crack surfaces is parallel to the plane of crack and perpendicular to crack front.

Fig. 3: Tearing mode is also called as out-of- plane mode i.e., displacement of crack surface is parallel to plane of crack and parallel to crack front.

IV. LITERATURE REVIEW ON CRACK MOUTH OPENING DISPLACEMENT (CMOD)

It is very laborious to study the direct determination of CTOD; the crack mouth opening displacement (CMOD) has been assesed during fracture tests of concrete beams and then related to CTOD. One of the important parameters of the fractures in concrete is Crack tip opening displacement (CTOD). To calculate the CTOD the Crack mouth opening displacement (CMOD) is quantified by the fracture tests on the concrete beams. Fiber optic sensers has been employed for direct determination of CTOD which were implanted in concrete.

The aprisal of the analytical schemes estimation of CTOD has been correlated with the measured displacements of CTOD and CMOD [1].

It was determined how far the ductility of concrete can be improved by the addition of steel fibers in terms of fracture parameters by varying the fiber content. The fiber content was varied from 0% to 1% with an increment of 0.25%. Three point bending test on notched beams (fracture tests) were conducted for determination of fracture parameters. The tests were done as per the guidelines of International Union of Laboratories and Experts in Construction Materials, Systems and Structures (RILEM) [2].

Concrete is one of the heterogenous materials. The concrte posse's high compressive strength compared low tensile strength of the concrete which enhances the cracks effortlessly. The width of the crack can be estimated by crack tip opening displacement or crack mouth opening displacement (CTOD/CMOD). There are several optical and non optical methods are there to determine the cracks present in the concrete. The intensity based plastic optic fiber method and fiber brag grating method were employed to know the Three point bend tests on pre-notched concrete samples [3].

The studyconducted on the crack depth and the profile of the cracks which evaluated the two and three three dimensional surface cracks. A coorealation as been devloped between the Crack Mouth Opening Displacement (CMOD) and crack depth was deduced through the Liner Finite Element Analysis (LFMA). Surface cracks actuated in two kinds of real structure were taken as examples to demonstrate how to employ the varying rules existing within proportional relation and some dominant factors are to be carried out depth estimation based on measured CMOD [4].

The composition of advanced fiber reinforced composites (AFRCs) unlike class of materials, the fibers which include carbon, glass, silicon carbide and polyaramid which are of a reinforcing phase and a matrix phase. Single mode fibers and double mode fibers are ustilised in concrete beams which evaluated the unique mechanical properties of the fiber types. The incorparation of the optical fibers and reinforcing fibers has affected diameter mismatch, which alters the long-term performance of the AFRC. The proposal of the optical fiber sensors can be employed at any stage in the filament winding process which has not been stuided in this paper. The due course resembling is the cost of the optical fibers is varying. [5].

The heterogenity of the concrete is prime movement for the experimental evaluation of the "width effect" and "size effect", which is the main concern in the uncerterninties of the above parameters. To analise influnance of the width and size of the concrete prisms are casted and tested on the different sizes. To study the strain near the crack tip in the quantitatively and qualitatively the Digital image correlation (DIC) was used [6].

In all the structures Cracks first appear on the surface of concrete structure under load and proved to be an indication for further degradation. The laser displacement sensor (LDS) is used for an efficient non-contact method of the detection of such cracks in concrete. During the scanning process, the system obtains the reading of displacement value from the sensor head to the laser spot on the target surface of the specimen.Two different concrete specimens have been tested to know the credibility of the concept, by employing a concrete slab with a 0.7mm width through crack and a cylindrical concrete specimen. A sharp distortion of the displacement reading observed when the laser spot passes the crack.

The minimal standard deviation proves the repeatability and accuracy of the measurement and shows that this technique can be related to a real-life scenario. A root-mean-square deviation in the displacement reading of the LDS is used as an index of crack. The effect of the shape of the specimen is investigated by detecting same-width cracks at different points along the circumference of a cylindrical specimen with different incident angles [7].

In this study, Beams with dimensions of 100×100×840 mm with a central notch sections and unnotched sections were investegated for the three-point bending. The un-notched beams specimens were tested as in the same set-up with reduced distance between supports. The tests were conducted in an hydraulic displacement controlled testing machine with a load capacity of 5 kN. Simaltanously, creck mouth opening displacement (CMOD) and loading and mid span displacement can be observaed in the test setup [8].

The two fracture parameters for Non-linear slow crack growth are critical stress intensity factor (K_c), critical crack tip opening displacement ($CTOD_c$). Experimental test was conducted for different beam size, two types of notches, materials under beam and tensile test. The fracture parameters are found to be size independent and could be calculated using R curve employed for LEFM. The proposed fracture criteria K and $CTOD_c$ can be experimentally determined from type G tests from the measured peak load and measured elastic crack mouth opening displacement [9].

The fracture parameters like fracture energy G_f and critical crack mouth opening displacement ($CMOD_c$) for PCC (Plain cement concrete) and FRC (Fiber reinforced concrete) using two parameter model and hillerborg model of fracture mechanics by conducting experiment under four point and three point loading. Resulted by load–deflection curve and load-CMOD curve. Using the curve and formulas fracture parameters were calculated for both PCC and FRC. The value of peak load for PCC and FRC do not differ much. The deflection of FRC is nearly by 25mm whereas for PCC deflection is 2mm before it gets fail. It was observed the TPM model is not accurate for FRC specimen.TPM model for FRC requires being efficient need some correction factor [10].

Focusing on interface properties like deformation, fracture energy, stress intensity by changing surface of aggregates, and cement composition and type of loading. Because of rough surface aggregate deformation and fracture energy increased. Crack mouth opening displacement (CMOD) is calculated by fixing aluminum angles at the face of the notch mouth near the surfaces of concrete i.e., at the smooth surface CMOD value was higher when compared to hardened surface. Composite specimen was prepared by adding silica fume tends to an increase in fracture energy and strength. Ductility and shear strength increase with increase of rough aggregate surface and area of bond between matrix and aggregate [11].

V. CONCLUSION

From this review paper, the following points can be studied and implemented for the further experimental work.

1. Development and experimental investigation will be done for optical fiber concrete beams with a notch.
2. Material dependent methods have to be implanted because crack pattern is mainly influenced by material property.
3. Usage of steel fibers in concrete will affects the fresh properties fresh concrete.
4. Three point bending test and wedge splitting test is very easier and appropriate methods for finding out mechanical fracture parameters like deformation, fracture energy etc.,
5. The intensity variation caused due to micro bending effect along the fiber.
6. The experiment is done for notched beams, the beams sizes were varying 100 × 100 × 500mm and 150 × 150 × 560 mm.

7. Notched Cylinders can also casted for testing the crack mouth opening displacement.

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