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Monitoring of impact of hooked ends on mechanical behavior of steel fiber in concrete

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HIGHLIGHTS

- The efficiency of Steel Fiber Reinforced Concrete (SFRC) is mainly related to the ability of the fiber and the concrete to work together homogeneously as hardened member.
- The homogeneous work SFRC components after hardening might be obtained through sufficient bond between the fiber and the concrete matrix at its contact points on the interface surfaces.
- If a smooth and straight steel fiber is embedded in concrete matrix and subjected to tensile force, only weak bond may obtain at the interface between the fiber and the concrete.
- If a single smooth and straight steel fiber is embedded in concrete matrix and subjected to tensile force, the bond strength decreases gradually and the fiber can't develop its yield strength, while debond length increases toward the depth of the concrete along the embedded length until failure occurs in bond strength between the fiber and the concrete.
- The fiber pulls out of concrete by frictional sliding movement when debond length reaches the far end of the fiber in the depth of the concrete.
- Computer simulations of single steel fiber (with hooked ends) embedded in concrete matrix are created and developed using finite element models to monitor the development of stresses in different directions.
- When using the sophisticated form of the fiber (with hooked ends), results showed enhancing in bond strength between the fiber and the concrete without changing in concrete mix properties.

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ABSTRACT

The efficiency of hardened composite of Steel Fiber Reinforced Concrete (SFRC) is mainly related to the ability of its components to work together homogeneously. This homogeneously work of SFRC components might be obtained through sufficient bond between the fiber and the concrete matrix at its contact points on the interface surfaces. Usually, if a smooth and straight steel fiber is embedded in concrete matrix and subjected to tensile force, only weak bond may obtain at the interface between the fiber and the concrete. This weak bond decreases gradually parallel with increasing the value of the applied tensile force in the pull-out test, and the fiber can't develop its yield strength, whereas debond length increases toward the depth of the concrete along the embedded length of the fiber until failure occurs in bond strength between the fiber and the concrete, then the fiber pulls out of the concrete through frictional sliding movement. The fracture mechanism of bond strength between the fiber and the concrete might be observed through pull-out tests. To enhance the bond strength performance of the fiber without change the concrete mix properties, it is necessary to find sophisticated form for the fiber such as end hooks. Monitoring of impact of hooked ends on mechanical behavior of steel fiber in concrete is observed during this research, where various pull-out experiments of single steel fiber in two forms (straight and hooked ends) are set using different values of embedded fiber length in concrete matrix. As well as computer simulations of single steel fiber with hooked ends embedded in concrete matrix are created using finite element model to monitor the development of stresses in different directions. Nonlinear results with contour maps and curves of different types of stresses are also obtained from the computer simulations, and numerical evaluation of the impact of enhancing the steel fiber shape has been done through this research.

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1. Introduction

The pull-out process, which is applied on the fibers in life cycle of hardened members of Fiber Reinforced Concrete (FRC), represents the mechanism which is usually used to evaluate the post-cracking behavior of fiber reinforced concrete composite, where the fibers resist the stresses that may cause cracks through pull-out mechanism [1,2].

Pull-out mechanism might be divided into sequent phases which are started by full bond phase between the fiber and the concrete without any cracks, and then phase of cylindrical cracks around the fiber at the interface between the fiber and the concrete matrix is shown, where these surrounding cracks increase gradually by greater debond length toward the fiber embedded length until cover all embedded length, and then the final phase starts by frictional sliding movement to pull the fiber out of the concrete [3–7].

Bond strength of hardened members of fiber reinforced concrete depends mainly on the friction at the interface between the fiber and the concrete, where frictional stresses generate along the interface and resist the extract process of the fiber from the matrix. Many factors affect these fictional stresses such as fiber end shape, water to cement ratio, curing method, and fiber dimensions and its embedded length in the concrete matrix [8,9].

During pull-out process the fibers are subjected to tensile force, which works to pull the fiber out of the concrete, whereas an interfacial bond stresses work to resist that subjected tensile force by fully bond stresses in first phase, followed by debonding as second phase, then frictional sliding as final pull-out phase [10–14].

Considered bond strength between the fiber and the concrete matrix is necessary to increase the performance of fiber reinforced concrete, where pull-out tests are usually used to evaluate this bond strength of the composite [15–20].

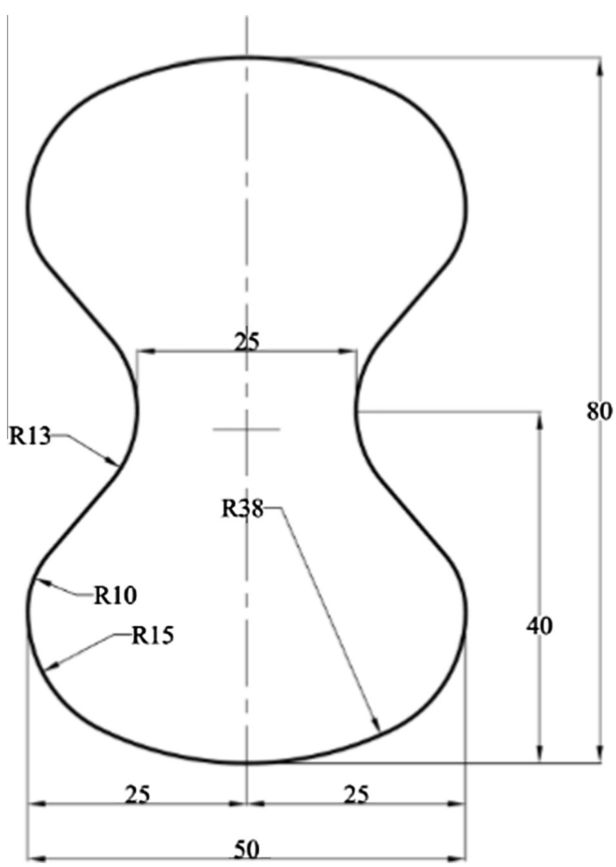

Fig. 2.1.1. Pull-out test specimen Model.


Fig. 2.1.2. Pull-out test specimen Mould.

Increasing the efficiency of hardened members of Steel Fiber Reinforced Concrete (SFRC) is mainly related to the ability of its components to work together homogeneously. This homogeneously work might be obtained through sufficient bond between the fiber and the concrete matrix at its contact points on the interface surfaces.

The fracture mechanism of bond strength between the fiber and the concrete might be observed through pull-out tests. To enhance the bond strength performance of the fiber without change the concrete mix properties it is necessary to find sophisticated form such as end hooks.

Monitoring of impact of hooked ends on mechanical behavior of steel fiber in concrete will be observed during this research, where various pull-out experiments of single steel fiber in two forms (straight and hooked ends) will be set using different values of embedded fiber length. As well as computer simulations of single steel fiber with hooked ends embedded in concrete matrix will be created using finite element model to monitor the development of stresses in different directions. Nonlinear results with contour maps and curves of different types of stresses will be obtained from the computer simulations, and numerical evaluation of the impact of enhancing the steel fiber shape will be done during this research.

2. Materials and methods

2.1. Experimental procedure

Pull-out specimens of single steel fiber embedded in concrete are prepared in the lab using specific form with determined dimensions according to the model in (Fig. 2.1.1), this figure shows the total area of the concrete matrix, where this total area will be divided into two symmetrical parts in the mid-length (40 mm) and the narrow region of the sample (25 mm), and each part will be subjected gradually to increased tensile force until a failure in bond strength between the fiber and the concrete.

The fresh concrete in preparation process of pull-out samples in the lab will be casted inside steel moulds, which have same dimensions of the previous suggested pull-out test specimen model as shown in (Fig. 2.1.2), where the total thickness of the mould equals to (10 mm).