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Efficiency of using discrete fibers on the shear behavior of R.C. beams

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Abstract The shear failure of R.C. beams are brittle and suddenly occurs. Using of discrete glass fibers with concrete mixes enhanced the ductility and deformability of R.C. members. This study aims to understand and evaluate shear behavior of discrete glass fiber concrete beams. The experimental investigation carried out on reinforced concrete beams with discrete glass fiber mixes. The studied parameters included stirrups spacing (50, 75, and 100 mm) and weight percent of discrete glass fiber 0.0%, 0.75%, and 1.5% respectively. The elastic behavior of tested beams at flexural zone was also investigated. Experimental results indicated that the shear strength of tested beams was significantly increased as the percentage of fibers increased. The number of the cracks increased by using discrete fibers and became finer. Moreover, the crack propagation and modes of failure may be changed by using discrete fibers. Finally the discrete glass fibers increase ductility and failure loads of the tested beams.

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1. Introduction

Glass fiber reinforced concrete (GFRC) is a cement based composite product that is reinforced with glass fibers. GFRC is a relatively new type of building material and increasingly being used in different countries and has many architectural applications [1]. Adding of glass fibers to concrete mixes increase its durability and sturdiness. While the regular concrete mixes is normally used at a fraction of the weight, GFRC can be used anywhere. Among the main advantages of GFRC are lightweight, high moisture resistance, high compressive strength, low maintenance, low thermal expansion and high fire resistance respectively [1–16].

The problem of determining the shear strength of reinforced concrete beams not closed up to know. Thus, the shear strengths predicted by different current design codes for a particular R.C.

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beam section can vary by a factor of greater than 2 [4]. In contrast, the flexural strengths predicted by the same codes are unlikely to vary by more than 10%. For flexure behavior of R.C. beams, the plane sections hypothesis forms the basis of a universally accepted, simple, rational theory for predicting flexural strength. In addition, simple experiments can be performed on reinforced concrete beams subjected to pure flexure and the clear results from such tests have been used to improve the theory. In shear, there is no agreement for a rational theory, and experiments cannot be conducted on R.C. beams subjected to pure shear [4].

While hundreds of tests have been under taken on the shear behavior of R.C. beams, the test pool of fiber-reinforced specimens are few. Fewer still are tests with fiber reinforced concrete members where the fiber concrete is designed to carry the full shear capacity [5]. The theory of concrete plasticity provides a good basis for shear design of SFR-UHPC (Steel Fiber Reinforced-Ultra High Performance Concrete) beams as the use of high quantities of ductile steel fibers in the concrete matrix leads to a relatively plastic response after cracking of the matrix with high tensile strengths maintained for large crack openings [15].

Previous results show that the nominal stress at shear cracking and the ultimate shear strength increased with increasing fiber volume, decreasing shear span-to-depth ratio, and also increasing the concrete compressive strength. Moreover, as the fiber content increases, the failure changes from shear to flexure mode [6].

The diagonal shear failure of reinforced concrete beams has long known to be a brittle type of failure. Therefore, a larger safety margin is provided by the capacity reduction factor in the codes [7]. The present code formulas have been calibrated to provide adequate safety against the initiation of diagonal shear cracks. However, the crack initiation load is not proportional to the ultimate load. It can be much smaller, or only slightly, depending on the beam size and other factors. Therefore, the existing design formulas cannot be expected to provide a uniform safety margin against failure. Ideally, the design should insure proper safety margins against failure and crack initiation [7].

The primary purpose of inclusion of steel fibers in conventionally R.C. members is not for increasing strength. The strength can be increased more easily and economically by using steel bars placed along the direction of principal tensile stresses. The deficiencies of ordinary R.C. in the form of micro-cracks, which cannot be corrected by bar reinforcement, can be remedied to a significant extent by using fiber reinforcement. Addition of randomly oriented fibers in plain concrete mixes help to bridge and arrest the cracks formed in the brittle concrete under applied stresses, and enhances the ductility and energy absorption properties of the composite [8].

The main objective of this search is to study the performance and the efficiency of using discrete glass fibers on the shear behavior of R.C. beams. Moreover, a comparison between the shear efficiency of increasing traditional transverse reinforcement (stirrups) and using discrete glass fibers with stirrups is presented. Finally, the test failure loads are compared with the prediction shear values of the codes.

2. Experimental work

Five R.C. beams with rectangular cross-section, sized 150 mm (width) × 150 mm (height) × 900 mm length, were manufactured and tested as shown in Fig. 1. Two parameters were considered in this study; variable discrete glass fiber ratio by weight, and variable distance between the stirrups, respectively. Details of these two parameters are shown in Table 1. The target concrete compressive strength is obtained from the average of three tested cubes (150 × 150 × 150 mm) from each batch.

Loads were applied by using a hydraulic jack of 550 kN capacity connected to a steel space frame. The four points symmetrical loading with distance 150 mm between the loading points were statically applied to all tested specimens. The shear span-to-depth ratio was being constant to all of the tested beams. All specimens were tested up to failure under monotonic loading.

Concrete mix used to cast the tested R.C. beams consisted of Portland cement, natural sand and gravel as aggregates and water. Specimens were cured at about 95% relative humidity. Dry sand and cement were mixed mechanically, and then water was added and mixed thoroughly. Mixing operation was continued after adding water until a uniformly color was obtained. The mixing proportion of different materials was by weight of cement. The concrete was cast in the steel molds having a smooth surface and these surfaces were coated with oil before casting. The average characteristic concrete compressive strength for tested beams without fibers is 23 MPa and for beams with fiber ratios, 0.75% and 1.5% is 25 MPa and 26 MPa, respectively.

The properties of the used glass fibers are as follows: fiber length is 15 mm with young's modulus of 72 GPa, a shear modulus of 29.1 GPa, an ultimate tensile strength of 1600 MPa, and an ultimate tensile strain of 2.2%, respectively (based on the manufacturer).

Digital Load cell of capacity of 550 kN with accuracy of 0.1 kN was adopted to measure the applied loads. The values of the applied loads were recorded from the monitor connected to the load cell. The beams were tested using an incremental loading procedure. The vertical displacement of the tested beams was recorded using two electric dial gauges, one at the middle of beams and the other at distance equal to half of the beam depth from the support. The strains at mid-span section were measured by using demic points. Fig. 1 shows the positions of the electrical strain gauges, dial gauges and demic points. During tests, the applied load was kept constant at each load stage for measuring and observing.

3. Test results and analysis

All the tested beams failed in shear as it was expected. The values of ultimate shear loads, failure modes, and percentage of load increase based on the ultimate load of control beam are given in Table 2. As shown in this table, the discrete glass fibers increased the ultimate capacity of the tested beams. The percentage of increased load reached to about 30% when the fiber ratio was increased to 1.5%. On the other hand, the ultimate capacity of R.C. beams increased only by about 16%, when the distance between stirrups are 50 mm. Consequently, the use of discrete glass fibers had a significant effect on the failure load with span-to-depth ratio equal 5 shear span-to-depth ratio equal 2.0, respectively. In this field work the role of discrete glass fibers on the shear behavior of R.C. beams needs further experimental investigation and will be done in another article.

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