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A comparative study of the effect of adding steel fiber on the mechanical behavior of RSCC beams under displacement and force control conditions

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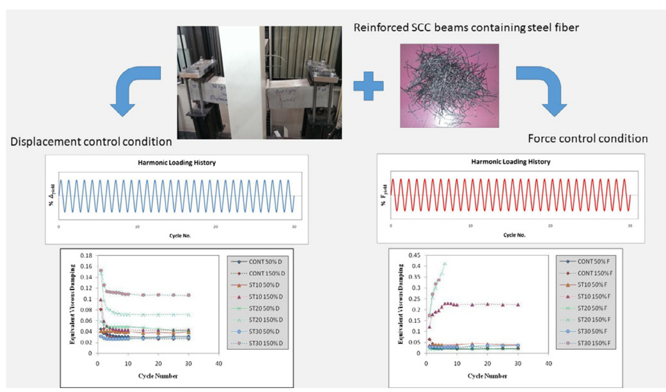
HIGHLIGHTS

- In pre- yielding amplitude, a negligible difference was observed in the results of stiffness and damping.
- In post- yielding amplitudes, with the increase of fiber fraction, the variations of stiffness and damping were was more intense for force control condition.
- For testing structural members under quasi-static loading, it is necessary to utilize the control condition that is most similar to the real nature of the loading.

GRAPHICAL ABSTRACT



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ABSTRACT

An experimental program is carried out on 32 reinforced self-compacting concrete (RSCC) beams containing various fractions of steel fiber under different cyclic loading control conditions. For this purpose, concrete beams with 4 mix designs of (RSCC) containing fiber (0.1, 0.2 and 0.3% volume fraction) and (RSCC) without fiber as the reference concrete were subjected to harmonic cyclic loading. The results achieved from this investigation indicate that in the displacement-controlled condition, with the increase of fiber fraction, the cyclic behavior of the specimens improves and in the after-yielding region of loading, this increment results in more obvious discrepancy among loading conditions.

1. Introduction

Fiber is added to the concrete in order to increase ductility, energy absorption, and dissipation capability, and to create an integrated system. It changes the behavior of materials when they crack by bridging between the cracks. Fiber also provides after cracking ductility which is lacking in plain concrete [1–3].

Ductility, energy dissipation capacity and damages occurred during cyclic loadings, are of behavioral aspects which cannot be confidently determined by analytical methods. Various experiments such as dynamic and quasi-static cyclic loading tests can be undertaken to simulate earthquakes. Unlike dynamic tests such

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as shaking table, which uses an acceleration time-history for simulating earthquake and contains both force and displacement variations, amplitudes in quasi-static cyclic tests are generally controlled by either force or displacement terms. This is considered as a limitation of quasi-static cyclic tests.

In geotechnology, studying the soil specimen behavior affected by liquefaction, i.e. allowing the soil to experience high strains, relevant tests are carried out under stress controlled conditions and by given cycles which depends on the intensity of the earthquake [4]. However, when the soil is not allowed to have significant deformations, the application of cyclic loads in a strain-controlled situation would provide a more realistic behavior. This concept is also feasible for structural elements.

Seismic designs and retrofitting codes mainly offer a formulated pattern for applying to the specimens [5–7]. These loading histories have a concept of deformation as a parameter for controlling load exertion. As a result, experiments would be carried out under displacement controlled condition only while vibrations caused by earthquakes are in a combination form of force and displacement. Therefore, seismic designs and retrofitting code methods are unlikely to properly simulate earthquakes.

As force control loading depends on properties of the member and environmental conditions, it is not possible to give a formulated pattern. In order to run experiments in a force controlled situation, a few guidelines have provided some recommendations such as FEMA461 [8].

Loadings in the form of quasi-static are applied to the specimens in three general ways: a) in most cases, a parameter of deformation such as drift ratio [9–13], percent of yielding displacement [14–16] or other parameters related to behavioral specifications is used [17–20]; b) in some experiments, loading history is applied as a two-part procedure including a combination of displacement and force control [21–23]. Even in this cases, both displacement and force parameters are not considered in loading histories simultaneously and; c) in few studies, loading amplitudes are controlled by force parameters [1,24].

In this paper, the author tends to run cyclic tests to examine the impacts of adding fiber to concrete on the outcomes of displacement and force controlled conditions. The whole process is discussed in three zones; before, near and after the yielding point. This has allowed to separately investigate the elastic and plastic behavior of specimens.

For this purpose, beams with different fractions of steel fiber were tested in different loading controls and amplitudes. Hysteresis curves, stiffness degradation, energy dissipation and equivalent viscous damping of beams are achieved and analyzed. The paper concludes that adding different fractions of fiber to concrete leads to various responses under force control and displacement control loading conditions.

2. Experimental investigation

In this study, full scaled RC beam specimens were tested under monotonic and quasi-static cyclic loading. In the following sections, geometry of specimens, material properties, loading apparatus and loading history is explained.

2.1. Details of specimens

32 RC beams with identical geometry and reinforcement detailing were fabricated in laboratory. The cross section of specimens was 150 × 200 mm with the length of 1300 mm. The effective length between the supports was 1100 mm. Dimensions and rebar of specimens are shown in Fig. 1. Two ribbed bars of 8 mm diameter were used for longitudinal reinforcement for top and bottom of the specimens. Concrete cover thickness from the center of the longitudinal bar to the surface of concrete was 40 mm.

For describing the type of tested beams (fiber percentage, cyclic loading amplitude, and type of loading control), abbreviation symbols were used according to the following format:

Xa b c

In the above format, the phrase Xa shows the mixing ratio for specimen. In case of using fiber, the word ‘a’ indicates the amount of fiber used in the specimen and according to the mixing ratio for this study would be 10, 20 or 30. The word ‘b’ explains the ampli-

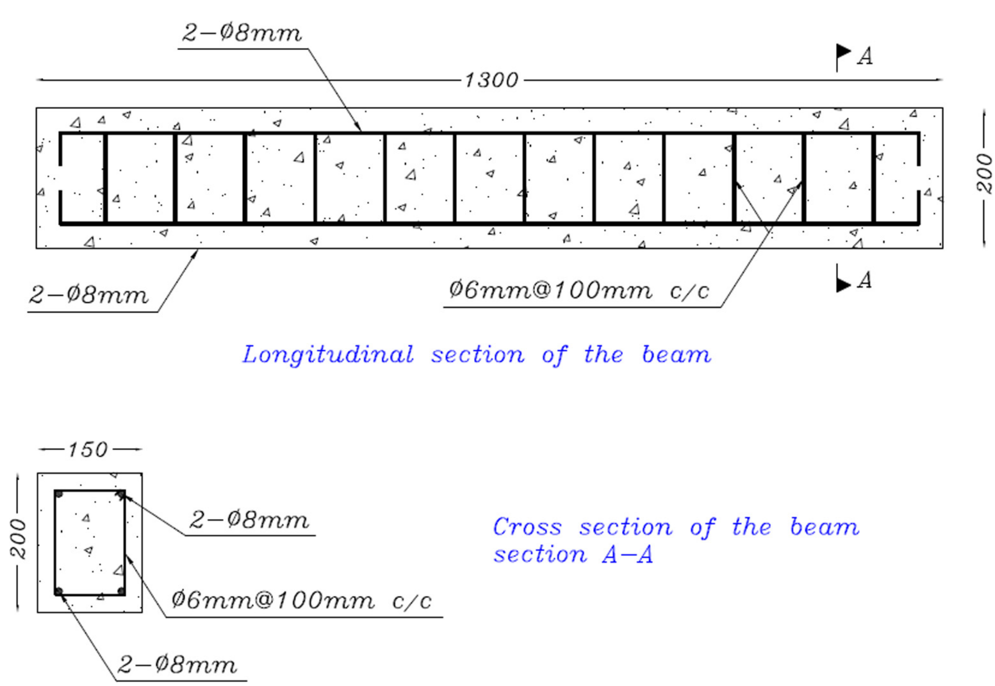

Fig. 1. Details of geometry and reinforcing specifications.