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Behavior of post-tensioned fiber concrete beams

Hossam-eldin Abd-elazim Elsharkawy [a], Tamer Elafandy [b,*], Abdel Wahab EL-Ghandour [b], Amr Ali Abdelrahman [b]

[a] *Dept. of Structural Engineering, Ain Shams University, Cairo, Egypt*
[b] *Dept. Housing and Building National Research Center, Giza, Egypt*

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Abstract This paper presents an experimental and analytical study on the behavior of post-tensioned concrete beams with variable discontinuous fibers' content. Eleven half scale T-shaped post-tensioned simple beams were cast and tested in four points bending under the effect of a repeated load using a displacement control system up to failure. The test parameters were the fibers' type (steel and polypropylene) and content, as well as the prestressing ratio (partially or fully). Key test results showed considerable enhancement in the crack distribution, crack width and spacing, concrete tensile strength and flexural stiffness in all beams with steel fibrous concrete. The latter aspects were directly proportional to the steel fibers' contents. On the other hand, beams containing polypropylene fibers demonstrated a slight decrease in the flexural strength and a slight increase in flexural stiffness. In addition, the tensile steel strains decreased in all fibrous concrete beams, with lowest values in steel fibrous concrete specimens when compared to those of the polypropylene fibers. Furthermore, fibrous concrete beams also demonstrated enhanced ductility and energy absorption, which reached the highest values for steel fibrous concrete specimens. Generally, it can be concluded that steel fibers proved to have higher structural efficiency than polypropylene fibers, when used in the tested specimens.

Introduction

Prestressed concrete has emerged very quickly as the predominant material in use in the construction industry, but the concrete has low tensile strength and low ductility. Over the past 10 years, there has been a steady increase in the use of fiber reinforced concrete (FRC) to help overcome the low tensile strength and ductility of concrete. The fibers were added to control the cracking of reinforced concrete, and to alter the behavior of the material once the concrete has cracked by bridging the cracks and, hence, providing post-cracking ductility. Recently, the building code requirements for structural concrete (ACI 318-08) [1] mentioned steel fiber in two chapters (material-shear & torsion). The available research in the area of post-tensioned prestressed beams using concrete containing fibers (3–10) is very sparse. Accordingly, necessary research has to be done in order to evaluate the effect of fibers on the

* Corresponding author.
E-mail addresses: hosharkawy@yahoo.com (H.-e.A.-e. Elsharkawy), tamer_elafandy@yahoo.com (T. Elafandy).

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behavior of post-tensioned prestressed beams from ductility and serviceability perspectives.

This paper presents an experimental investigation in the behavior of post-tensioned fibrous concrete beams when tested under repeated load using the displacement control system up to failure. The fibers contents' ratios, type of fibers (steel and polypropylene) as well as the prestressing level (partially or fully) were the main parameters investigated. The test results including capacity, crack patterns, deflection, and tensile steel strain in the flexural reinforcement are presented and discussed. Key structural aspects of behavior including ductility and energy absorption are also discussed. In addition, a previously proposed analytical model [3] was used to predict the test results. The validation of the model was established through comparisons with tests. Finally, design oriented conclusions are highlighted.

Experimental work

Beam details

Figs. 1 and 2 show the geometry, supports arrangement, internal reinforcement and prestressing profile of all tested specimens, which consisted of eleven half scale post-tensioned simple beams with typically T-shaped cross-section and equal spans. All beams had the same overall dimensions with a total length of 5400 mm, an overall height of 300 mm and a clear span of 5000 mm. The dimensions of the flange were 350 mm × 60 mm and the web dimensions were 240 mm × 150 mm, as shown in the figures. All beams were designed according to ACI 318-08 [1] to have the same ultimate moment capacity. The prestressing profiles were kept the same for all beams. The web stirrups in all beams were consisting of 2 vertical branches of 10 mm diameter bars that were horizontally spaced at 100 mm, in order to prevent shear failure occurrence prior to the flexural failure. In addition, the transverse reinforcement of the flanges consisted of 8 mm diameter bars spaced at 200 mm. All the prestressing strands comprised of seven wires with a nominal diameter of 12.7 mm and 15.24 mm for partially prestressed and fully prestressed beams, respectively. The beams were divided into three groups according to the partial prestressing ratio (PPR) and the types of fibers. Group one comprised four specimens coded B1-FP-0-0, B2-FP-0.5-S, B3-FP-1-S and B4-FP-1.5-S, and reinforced with prestressing strands only in order to simulate the full prestressing system (PPR = 1). In the previous beams, the steel fibers' contents were 0, 0.5%, 1%, and 1.5% of the concrete volume respectively. Group two consisted of four specimens reinforced with prestressing strands and flexural reinforcement, in order to simulate the partial prestressing (PPR = 0.73) system. The specimens of this group were coded B5-PP-0-0, B6-PP-0.5-S, B7-PP-1-S and B8-PP-1.5-S with steel fibers' contents of 0%, 0.5%, 1% and 1.5% of the concrete volume, respectively. Finally, group three consisted of three specimens reinforced with prestressing strands and flexural reinforcement similar to the second group, but with polypropylene fibers' contents of 0.5%, 1%, and 1.5% of the concrete volume. Beams coded B1-FP-0-0 and B5-PP-0-0 without fibers were used as control beams for the fully prestressed (PPR = 1) and the partially prestressed (PPR = 0.73) conditions, respectively.

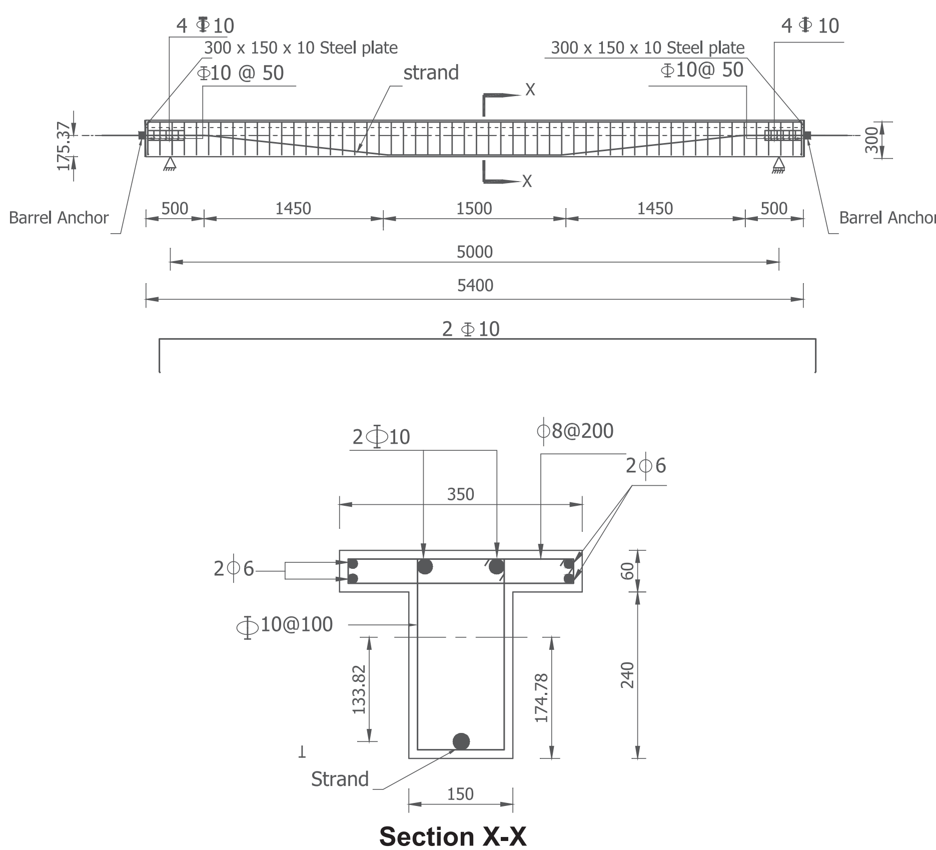

Fig. 1 Flexural reinforcement for fully prestressed beams of group one. Typical details for fully prestressed beams of group one.