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Influence of fibers on flexural behavior and ductility of concrete beams reinforced with GFRP rebars

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ABSTRACT

This research studies the influence of fibers on flexural behavior and ductility of concrete beams reinforced with GFRP bars. The experimental program included seven beams. The tested beams were divided into four groups. Each of the first three groups consisted of two beams one of normal strength and the other of high strength while the fourth group consisted of one normal strength beam. The first group is the reference group which had no internal fibers. The second group studied the effect of using internal polypropylene fibers in the concrete mix. The third group studied the effect of using internal glass fibers in the concrete mix while the fourth group studied the effect of using internal steel fibers in the concrete mix. The experimental results of tests showed that using GFRP as the main reinforcement for the concrete beams achieves reasonable flexural strength. Also the theoretical results calculated using ACI 440 code showed good agreement with the experimental results with an error of about 20%. The results of the current research indicated that all types of the fibers used improved the ductility of FRP- reinforced concrete beams. It was found that the span-to-experimental service load deflection ratio is relatively high when compared to the usually accepted ratio of about span/250.

1. Introduction

The use of fiber-reinforced polymer (FRP) bars to replace steel reinforcement in concrete structures is a relatively new technique. With regard to the inherent corrosion nature of conventional steel, FRP rebars seem to be a promising alternative as internal reinforcement for concrete. FRP rebars are ideally suited to reinforce concrete elements in aggressive environments [1]. In addition, some of the most important benefit of FRP reinforcement is in structures where reinforcement with non-metallic properties is required for example in the surroundings of some medical equipment or where a member must have a high strength to weight ratio. Another important advantage of this material is that it is easy to handle, which reduces the application time and total cost. Therefore, this is a great benefit especially in repair or retrofit works. FRP bars possess mechanical properties different from steel bars, including high tensile strength combined with low elastic modulus and elastic brittle stress–strain relationship. Due to the linear elastic brittle behavior of FRP bars, the flexural behavior of FRP-reinforced concrete beams exhibits no ductility [2–4].

The major aim of this paper is to improve the ductility of beams reinforced with FRP rebars. To achieve this target, the concrete's mechanical properties must be enhanced. ACI 440.1R-06 [5] recommends that the FRP-reinforced concrete beams must be over-reinforced so that they fail by concrete crushing rather than by rebar rupture. Thus, the ductility of the system is strongly dependent on the concrete's properties. It is well known that the fibers improve the mechanical properties, toughness, and ductility of concrete. The review of literature shows that some trials were made to improve the ductility of concrete members reinforced by FRP rebars. Taniguchi et al. [6] showed that confining the concrete beams with the helical shape of FRP bars can highly improve the ductility of FRP-reinforced beams. However, as the FRP bars are more expensive than conventional steel bars the proposed solution of using the helical FRP may not be a practical one to overcome the ductility problem. A better and a more convenient way to defeating such an obstacle may be through mixing short steel fibers (SF) with the concrete mix. Swamy and AL-Noori [7] observed that the presence of steel fibers enables high strength steel with yield strength of 700 MPa to be used with both crack width and deflection being controlled within acceptable limits. They also observed that beams reinforced with such high yield reinforcement could be made to behave in a ductile manner by the use of steel fibers. Swamy and AL-Ta'an [8] carried out flexural tests on 15 concrete beams reinforced with steel bars and steel fibers (SF). The volume and location of SF were the main variables

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