Ductile Design of Reinforced HSC Beams Retrofitted with FRP Plates

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Abstract

For high-strength reinforced concrete beams (HSRC) retrofitted with fiber-reinforced polymer (FRP) plates, an analytical method is derived for determining the allowable plate area to achieve a targeted value of ductility. Nonlinear models for concrete and reinforcement are applied. The derivation of equilibrium and compatibility equations for a rectangular cross section is presented, and the solution to the nonlinear equation for determining the allowable plate area is demonstrated with example. Analytical results are compared with experimental data reported in the literature. It is noted that additional conditions need to be checked to ensure ductile performance, such as local failure of the concrete layer between tension reinforcement and FRP plate or debonding of the plate itself.

Keywords: High Strength Concrete, RC Beams, Retrofiting, FRP, Ductility.

1. INTRODUCTION

In seismic areas, ductility is an important factor in design of HSC members under flexure, consequently the use of HSC beams strengthened with CFRP and ductility that has not been focus in much of the previous research will focus in this study.

When the strength of concrete gets higher, some of its characteristics and engineering properties become different from those of normal-strength concrete (NSC) (Hashemi et al. 2008). These differences in material properties may have important consequences in terms of the structural behavior and design of HSC members. The design provisions contained in the major building codes are, in reality, based on tests conducted on NSC. While designing a structure using HSC, the designer—particularly in the Southeast Asian region—usually ignores the enhanced properties of concrete and possible changes in the overall response of the structure because of lack of adequate code guidance (Rashid 2002). Earlier research concluded that although the tensile strength and fracture energy increase with an increase in compressive strength, High Strength Concrete is less ductile than normal concrete in both tension and compression.

Although external strengthening of RC beams using epoxy-bonded FRP has been established as an effective tool for increasing their flexural and/or shear strength, the method still suffers from some drawbacks. Many of these drawbacks are attributed to the characteristics of currently available commercial FRP strengthening systems. Although FRPs have high strengths, they are very brittle. From the point of view of seismic performance the additional tensile area introduced may result in less ductility, generally characterized by brittle failure of concrete flexural compression. When loaded in tension, FRPs exhibit a linear stress-strain behavior up to failure without exhibiting a yield plateau or any indication of an impending failure.

The design of FRP-retrofitted HSRC beams in term of ductile performance has not received adequate attention in previous research. Oztekin et al. (2003) obtained new stress-strain parameters of HSC from experimental stress-strain diagram. Also, they obtained new equivalent stress block parameters at only ultimate strain not for any given concrete strain. Lee and Pan et al. (2004) presented an algorithm and simplified formulas for estimating the relationship between the ratio of FRP plate area and ductility of reinforced NSC beams. Therefore the objective of this investigation is to study the effectiveness of FRP sheets on ductility and flexural strength of HSRC beams. In this paper, an analatical method is derived for determinating the allowable area of FRP plate ratio for rectangular HSRC beams retrofitted with FRP plates to achieve a ductility target specified by designer. The method is suitable for seismic design applications.