9th International Congress on Civil Engineering, May 8-10, 2012
Isfahan University of Technology (IUT), Isfahan, Iran

Grooving Method and Its Effect on Flexural Failure Mechanism of Concrete Beams Strengthened with FRP

Davood Mostofinejad [1], Amir reza Moghaddas [2]
1- Professor
2- Graduate Student
Department of Civil Engineering, Isfahan University of Technology (IUT), IRAN
Email: dmostofi@cc.iut.ac.ir
Email: a.moghaddas@cv.iut.ac.ir

Abstract
Amongst various methods developed for strengthening and rehabilitation of reinforced concrete (RC) beams, external bonding of fiber reinforced polymer (FRP) to the beam has been widely accepted as an effective and convenient method. This paper presents the experimental results of testing 6 reinforced concrete beam specimens designed in flexural failure modes of concrete crushing and FRP rupture after steel yields with the dimensions of 120×140× 1000 mm, were cast and strengthened with FRP laminates in two methods of externally bonded reinforcement (EBR) and the new one of externally bonded reinforcement on grooves (EBROG). The results indicate EBROG is more effective than EBR to control debonding and increasing load carrying capacity of beam.
Keywords: FRP, EBR, Grooving method, Debonding, Flexural failure mechanism.

1. INTRODUCTION

Although steel and concrete continue to maintain their importance as building materials and are the two materials of choice in infrastructure today, there is an increasing need for the development of advanced materials and techniques especially for the rehabilitation of aging infrastructure fabricated from these materials [1].

FRP composites, because of their unique advantages, such as high strength to-weight ratio and considerably good resistance to corrosion, over the conventional steel bars and plates have been widely applied to the strengthening and upgrading of structurally inadequate or damaged concrete structures [2]. Flexural strengthening of reinforced concrete beams, slabs, walls, and columns is achieved by attaching an FRP strengthening system (bonded strip or saturated dry fabric) to the tension face of a flexural member to increase the effective tensile force resultant in the member and thereby increase the moment capacity of the member [3].

In the flexural strengthening of reinforced concrete beams with externally applied FRP sheets or strips, it is essential to understand the effects that the FRP reinforcement has on the beam failure mode, especially for the development of rational design equations under ultimate loading conditions. The review of the published literature on experimental studies on the response of RC beams strengthened with externally bonded FRP reveals that several different failure modes, from ductile to very brittle, were observed [4].

The following flexural failure modes should be investigated for an FRP-strengthened section [5]:

- Yielding of the steel in tension followed by concrete crushing;
- Crushing of the concrete in compression before yielding of the reinforcing steel;
- Yielding of the steel in tension followed by rupture of the FRP laminate;
- Rupture of the FRP laminate before yielding of the reinforcing steel;
- Shear/tension delamination of the concrete cover (cover delamination);
- Debonding of the FRP from the concrete substrate (FRP debonding).

The most desirable mode of failure is concrete compressive failure after the internal steel has yielded with the FRP strengthening system still attached. This is often difficult to achieve due to a mechanism that is known as debonding [3]. This failure mode depends on the bond behavior at the concrete-FRP reinforcement interface and generally happens with the detachment of a more or less thick concrete cover [6].

One of the most common methods for flexural strengthening of concrete beams with FRP materials is the Externally Bonded Reinforcement (EBR) [1]. Strengthening of structures with Grooving method (EBROG) is a technique that has attracted a considerable attention as a feasible to the technique of