



# A Parametric Study of ERR in RC Beams Strengthened by FRP Sheets and Debonding of FRP and Concrete Interface

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## Abstract

This paper investigates a parametric study method to evaluate the partial and total mode components for energy release rate (ERR) in strengthened reinforced concrete beams (SRCBs) by fiber reinforced polymer (FRP) sheets. Externally bonding of FRP sheets is a general method of strengthening RC beams. Debonding along the FRP and concrete interface may produce a sudden failure of structures. A strong bonding between FRP and concrete is an important parameter on the behavior of RC beams. Previous experimental results and analytical methods have shown that debonding in the FRP and concrete interface is a complex phenomenon. The previous researches show that six types of failure due to debonding phenomena exist in reinforced concrete structures strengthened with FRP sheets. In this paper, one of the most important and common debonding type has been chosen. This one type of debonding is the separation between of the FRP sheet and concrete beam at the end of their connection. The present paper provides a parametric study method in realization of debonding phenomena and its effects on behavior of concrete structures strengthened by FRP sheets using mixed mode debonding analysis. Finally, the concordance of the finite element analysis (FEA) and existed results proves that the accuracy of the parametric study proposed approach to predict the debonding phenomenon is quite acceptable.

**Keywords:** ERR, FRP sheets, SRCB, FEA, mixed mode debonding analysis.

## 1. Introduction

The composite materials such as fiber reinforced polymers (FRPs) carry out such a unique properties that can offer to the designers such a solutions by which they can upgrade or retrofit the existing concrete or steel structures. Their excellent mechanical properties such as high strength to weight ratio, stiffness to weight ratios, durability and their high resistance against environmental effects had made these materials to be used broadly in construction industry by structural designers, consulting engineers and contractor companies [1,2].

On the other hand, reinforced concrete (RC) beams being used for several years may be strengthened by externally bonded FRP sheet at places which are subjected to tension force. Nowadays the FRP sheets are used in several types, sometimes the CFRP and GFRP sheets are used separately and sometimes it is preferred to be used simultaneously in single element. It can be said that these sheets are mainly used to prevent a section from being cracked under service loads.

## 2. Background on debonding phenomena

The previous researches show that six types of failure due to debonding phenomena exist in the RC structures strengthened by FRP sheets. Numerous experimental results on retrofitted RC beams show that failures of mixed mode in FRPs bonded may be divided into various mechanisms which are: (1)- the concrete layer over rebar, (2)- reinforcing steel rebar outskirt, (3)- the adhesive layer and concrete beam interface, (4)- inside the adhesive film, (5)- the adhesive layer and FRP sheet interface, and (6)- inside the FRP sheet [1,3].

### 2.1. Debonding Survey (Analytical, Experimental and Numerical)

Different methods have been applied to study the shear and normal stresses of strengthened beam at FRP and concrete interface or to determine its ultimate strength [4]. These methods are: (1)- strength of materials (SOM) method, (2)- linear elastic fracture mechanics (LEFM) method, (3)- experimental method and (4)- nonlinear fracture mechanics (NLFM) method.