Hyperbox Modelling for Externally Bonded Carbon Fibre Reinforced Polymers on Beams

Alvin Chua, Dr. Jason Maximino Ongpeng, Dr. Kathleen Aviso

De La Salle University – Manila, NCR, Philippines

Contact: alvin_chua@dlsu.edu.ph, jason.ongpeng@dlsu.edu.ph, kathleen.aviso@dlsu.edu.ph

Abstract

Carbon fibre reinforced polymers (CFRPs) are common retrofitting materials accounting for their high strength, light weight, durability, among others. Due to the lack of a worldwide consensus, much research about externally bonded (EB) FRPs on beams focus on determining the shear capacity contribution (V_f), in which a parameter called the effective strain (ε_{fe}) is often used. The ε_{fe} is often limited by the governing failure mode (typically debonding). Factors like the complexity of shear phenomenon and composite systems hinder such consensus. Machine learning (ML) applications have been used to model complex behaviour using datasets. A hyperbox modelling ML approach with mixed-integer linear programming (MILP) is used, providing interpretability and versatility in results modelling. This study determines the V_f sufficiency of EB CFRPs on beams while minimizing prediction errors through the 8 rule-based models produced for the EB CFRP configurations.

Keywords: shear capacity; effective strain; debonding; rupture; machine learning; mixed integer linear programming

1 Introduction

Concrete structures are inevitably subject to environmental and/or mechanical degrading. Enhancing them back to their original structural integrity would require retrofitting [1]. Of the many materials used for concrete strengthening, carbon fibre reinforced polymers (CFRPs) are often used for their high strength-to-weight ratios, light weight, durability, among many other advantages.

In the context of shear-deficient beam retrofitting, external bonded (EB) configurations (side-bonded or U-wrapped) are preferred over complete wrapping schemes. The former is practiced more because of its practicality and cost-efficiency [1]. However, such configurations are nonetheless prone to failure modes like debonding and rupture.

Numerous studies, experimental and analytical, have been conducted to understand the shear contribution of EB CFRP on beams. Much of the design guidelines being used today are formulated from empirical data [2]. Moreover, the interaction of other reinforcing materials (e.g., rebars, stirrups) with the concrete, adhesive, and FRP adds to the overall complexity of the problem.

The models predicting the shear capacity of FRPs (commonly referred to as V_f) have similarities in the variables that they consider (e.g., geometrical characteristic of the beam). An aspect in which these equations tend to differ is in a parameter called effective strain, ε_{fe} (or in its alternate form, effective stress, f_{fe}) [3][4][14][15]. Researchers have tried various ways of determining this parameter in hopes to achieve a more accurate V_f. Apart from experimental methods, analytical