# Chapter 18

# Optimum Design of Carbon Fiber–Reinforced Polymer (CFRP) Beams for Shear Capacity via Machine Learning Methods:

## Optimum Prediction Methods on Advance Ensemble Algorithms – Bagging Combinations

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## ABSTRACT

*In this chapter, an application for demonstrating the predictive success and error performance of ensemble methods combined via various machine learning and artificial intelligence algorithms and techniques was performed. For this reason, two single methods were selected, and combination models with a Bagging ensemble were constructed and operated with the goal of optimally designing concrete beams covering with carbon-fiber-reinforced polymers (CFRP) by ensuring the determination of the design variables. The first part was an optimization problem and method composing an advanced bio-inspired*

DOI: 10.4018/978-1-6684-6291-1.ch018

*metaheuristic called the Jaya algorithm. Machine learning prediction methods and their operation logics were detailed. Performance evaluations and error indicators were represented for the prediction models. In the last part, performed prediction applications and created models were introduced. Also, the obtained predictive success of the main model, as generated with optimization results, was utilized to determine the optimal predictions of the test models.*

## INTRODUCTION

Artificial Intelligence (AI) methods are effective in solving multidisciplinary engineering problems. Also, AI methods can be trained with optimization methodologies to provide the prediction of optimization results. In this chapter, the authors present a study showing the application of the predictive success and error performance of ensemble methods employing various machine learning and artificial intelligence algorithms. Two single methods were selected, and combination models with a Bagging ensemble were constructed. The optimal design is that of using concrete beams with a covering of carbon-fiber-reinforced polymers (CFRP) by ensuring the determination of design variables for the minimization of CFRP material in order to increase the shear capacity of the beam. For an RC beam using CFRP, the width, spacing, and application angle of the CFRP strip are the design variables. Their optimization has previously been done (Kayabekir, Sayin, Bekdas, & Nigdeli, 2017; Kayabekir, Sayin, Nigdeli, & Bekdas, 2017; Kayabekir, Sayin, Bekdas, & Nigdeli, 2018; Kayabekir, Bekdaş, Nigdeli, & Temür, 2018) by using several metaheuristic algorithms—namely, Flower Pollination Algorithm (FPA) (Yang, 2012), Teaching-Learning-Based Optimization (TLBO) (Rao, Savsani, & Vakharia, 2011), and Jaya Algorithm (JA) (Rao, 2016).

## CARBON-FIBER-REINFORCED POLYMER (CFRP) BEAM MODEL

### The Optimization Problem

The capacity of reinforced concrete elements may be insufficient due to reasons such as a change in the purpose of use of the structure (for examples, adding a new floor to the existing structure or retrofitting it for a capacity increase due to earthquake force mitigation; etc.). In such cases, various retrofit methods are utilized to increase the shear force, flexural moment, or axial force capacities. These methods generally necessitate the partial destruction of existing members; and the use of such structures may not always be possible in such case. Furthermore, since the total weight and rigidity of the structure are changed, a structural re-analysis is required. Another option is to use carbon-fiber-reinforced polymer (CFRP), having a linear deformation behavior with a large strain capacity, without changing the existing behavior of the structure. This method can be easily applied and provides for the use of the structure during its application.

In this chapter, optimal carbon-fiber-reinforced polymer design is presented with the goal of increasing the shear capacity of T-shaped RC beam members. This is done by considering the rules of regulation ACI 318 (Building Code Requirements for Structural Concrete); and by following various advanced machine learning applications that were carried out. It was likewise done by determining these

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