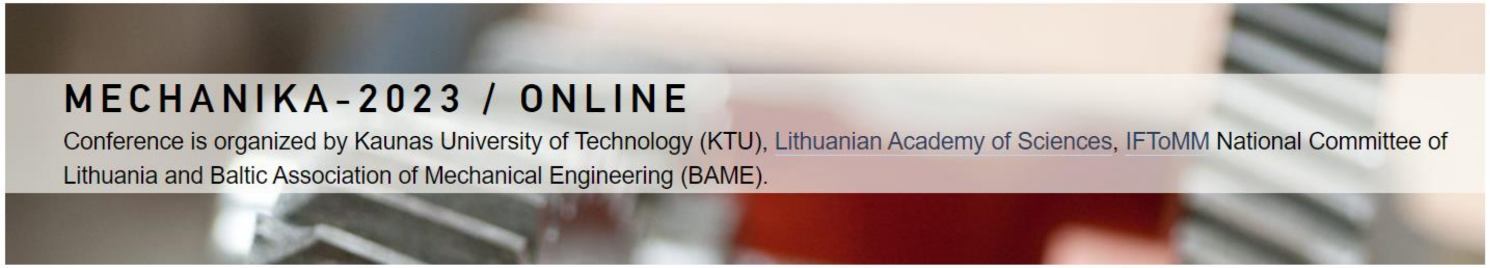

Mechanical Analysis of Reinforced Concrete Beams Strengthened with NSM FRP Technique: A Combined FEA and Artificial Neural Network Study

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1922

27th International Conference MECHANIKA '2023

Scopes

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1. Introduction

Reinforced concrete beams are widely used in construction due to their high strength and durability. However, these beams may undergo damage or degradation over time due to various factors such as exposure to harsh environmental conditions, excessive loading, and inadequate design. To overcome these issues, strengthening techniques such as the Near-Surface Mounted (NSM) Fiber Reinforced Polymer (FRP) technique have been developed. The NSM FRP technique involves the bonding of FRP bars or strips into slots or grooves created in the concrete surface along the length of the beam. The FRP material provides additional tensile strength and stiffness to the beam, thus enhancing its load-carrying capacity and prolonging its service life. Several researchers have conducted mechanical analyses of reinforced concrete beams strengthened with NSM FRP technique to evaluate its effectiveness.

1. Introduction

The mechanical analysis of reinforced concrete beams strengthened with NSM FRP technique is essential for understanding the behavior of these beams under different loading conditions. The analysis can provide valuable insights into the load-carrying capacity, stiffness, and ductility of the beams, as well as the effect of various parameters such as the size and spacing of NSM FRP strips or bars, the type of adhesive used, and the concrete strength. Several researchers have conducted experimental and numerical studies to analyze the mechanical behavior of NSM FRP strengthened concrete beams. For instance, Täljsten et al. [3] conducted three-point bending tests on reinforced concrete beams strengthened with NSM FRP strips and observed a significant increase in the load-carrying capacity and stiffness of the beams. Similarly, Gao et al. [4] conducted experiments on NSM FRP strengthened concrete beams and observed a significant increase in the load-carrying capacity and ductility of the beams. Moreover, numerical simulations have been conducted to investigate the mechanical behavior of NSM FRP strengthened concrete beams. For instance, Al-Mahaidi et al. [5] investigated the effect of NSM FRP strip spacing on the flexural behavior of reinforced concrete beams and observed that a smaller spacing resulted in a higher load-carrying capacity and ductility of the beams.

1. Introduction

In this literature, we will present an overview of the mechanical analysis of reinforced concrete beams strengthened with NSM FRP technique. We will review the experimental and numerical studies conducted in this field, focusing on the effect of various parameters on the behavior of the beams. The review will provide valuable insights into the effectiveness of the NSM FRP technique for strengthening reinforced concrete beams and highlight the need for careful design and evaluation of the NSM FRP strengthening system for each specific application. Furthermore, numerical simulations have also been conducted to analyze the mechanical behavior of NSM FRP strengthened concrete beams. Overall, the NSM FRP technique has been found to be an effective method for strengthening reinforced concrete beams. However, the effectiveness of the technique may depend on various factors such as the type of FRP material used, the size and spacing of FRP strips or bars, and the adhesive used. Therefore, it is essential to carefully design and evaluate the NSM FRP strengthening system for each specific application.

2. Materials and Methods

In order to compare the performance of reinforcement on the concrete beams, finite element (FE) models were designed based on experimental studies regarding beam performance evaluation. In the scope of numerical analysis simulations, two FE models of RC beam design were created including i) control beam and, ii) NSM FRP beam. Control beam consisted of reinforcement members including rebars and soffits, concrete and bearing members. Moreover, NSM FRP beam included reinforcement members, concrete, bearing members, epoxy and FRP components. In both RC models, stirrups had 10 mm diameter and placed at 100 mm interval to provide shear resistance and flexural strength to the models. In both models, rebars were designed so that two 12 mm and 8 in diameter steel bars placed in the bottom and top of concrete member, respectively. Concrete members for both models had a size of 300×150×2000 mm. In the NSM FRP model square epoxy and an FRP bar with a size of 10x10 mm were mounted near bottom surface. Control beam and NSM FRP beam models are shown in the Fig.1.

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2. Materials and Methods

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Fig. 1 RC beam models for control beam (left) and NSM FRP beam (right)

2. Materials and Methods

In the simulation of FE analysis, material properties for RC beam members were determined based on experimental studies [6]. Concrete members were assumed to be non-linear and isotropic materials in both models. Reinforcement members including rebars and soffits, bearing members, epoxy and FRP were considered as linear, isotropic materials. Material properties of beam components are given in Table 1.

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Table 1. Characteristic properties of the materials

Properties / Members	Concrete	Reinforcement	Bearing	Epoxy	NSM FRP
Density (kg/mm^3)	2.4E-6	7.85E-6	1.83E-6	1.56E-6	1.6E-6
Young's modulus, E (MPa)	32000	200000	1440	11200	16500
Poisson's ratio, ν	0.2	0.3	0.4999	0,22	0,2
Tensile ultimate strength (MPa)	640.2	500	-	25	-
Compressive ultimate strength (MPa)	47.2	-	-	75	75
Tensile yield strength (MPa)	4.72	420	-	-	35

2. Materials and Methods

Meshing procedure was performed on the both RC beam models to obtain a discretized geometry allowing FE simulations. Control beam and NSM FRP beam models had 12000 elements and 14544 nodes, and 14516 elements and 19483 nodes, respectively (Fig.2). Mesh size was 20 mm for both models and it was selected to reduce computational burden and to provide satisfactory performance, as well. In the simulations, supports were fixed and 5 mm displacements were applied on the concrete body for both models. Bonded contacts were assigned to regions were separate components connected to each other.

Stress distribution on the RC beam geometries was aimed to obtain using FEA simulations. Externally applied displacement as a loading condition brings about stresses and deflections which are considered as performance indicators. Throughout the simulations deflections and stress distributions on the models were determined.

2. Materials and Methods

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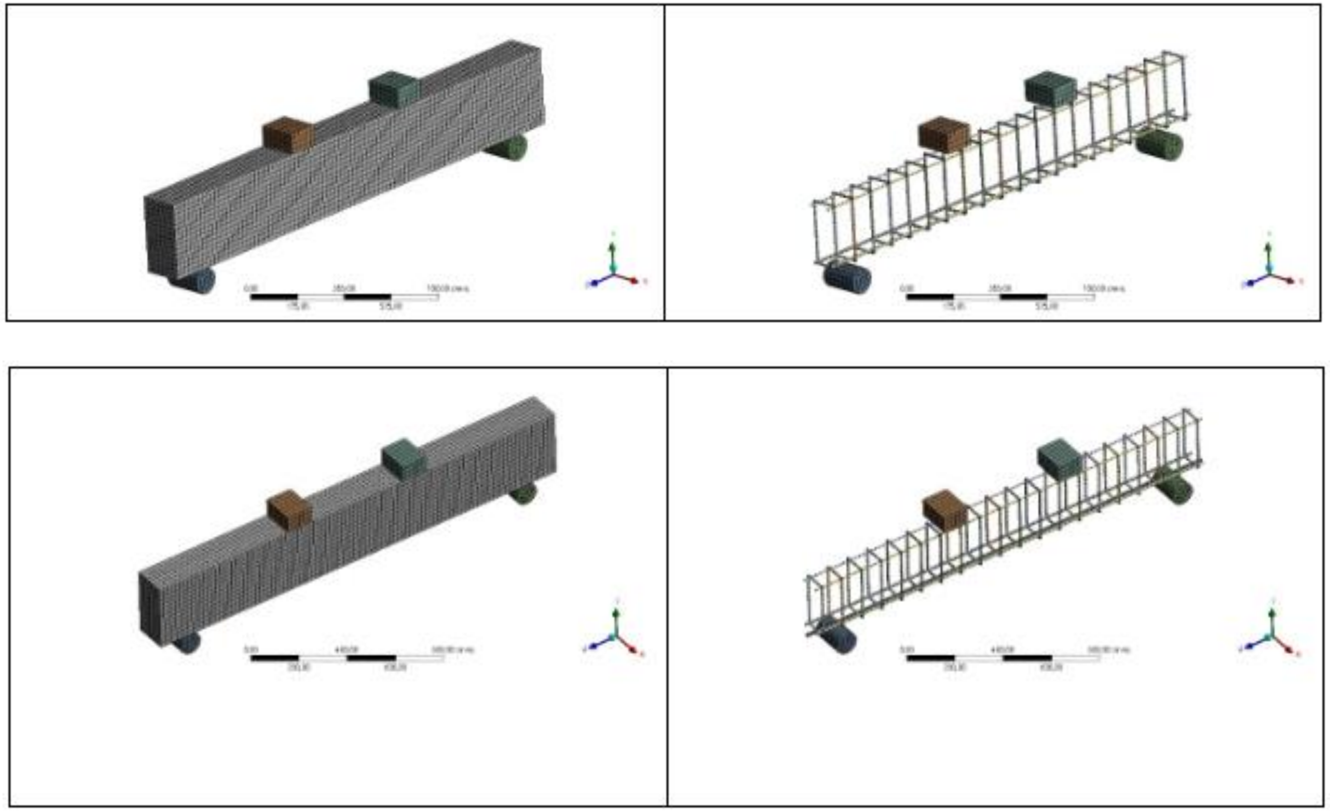

Fig. 2 RC beam models meshing. Control beam (top row) NSM FRP beam (bottom row).

2. Materials and Methods

Support Vector Machines (SVM) is a supervised machine learning algorithm used in classification and regression problems. SVM is widely used in many real-life problems such as marketing, text recognition and image classification. SVM is computationally easy, scalable, and resistant to outliers over other methods. SVM performs well in classification and regression problems even when there are few training data and many features. Also, there is no upper limit to the number of data used; also suitable for very large datasets [7].

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4. Results

As a result of the finite element analysis, the deformation and stress values provided in the control beam and strengthened beam are given in Fig.3. Regression analysis is performed using machine learning algorithm. The comparison of FEA and SVM are given in Fig.4. The values of error and R2 is found as 125,07 and 0,99 respectively.

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4. Results

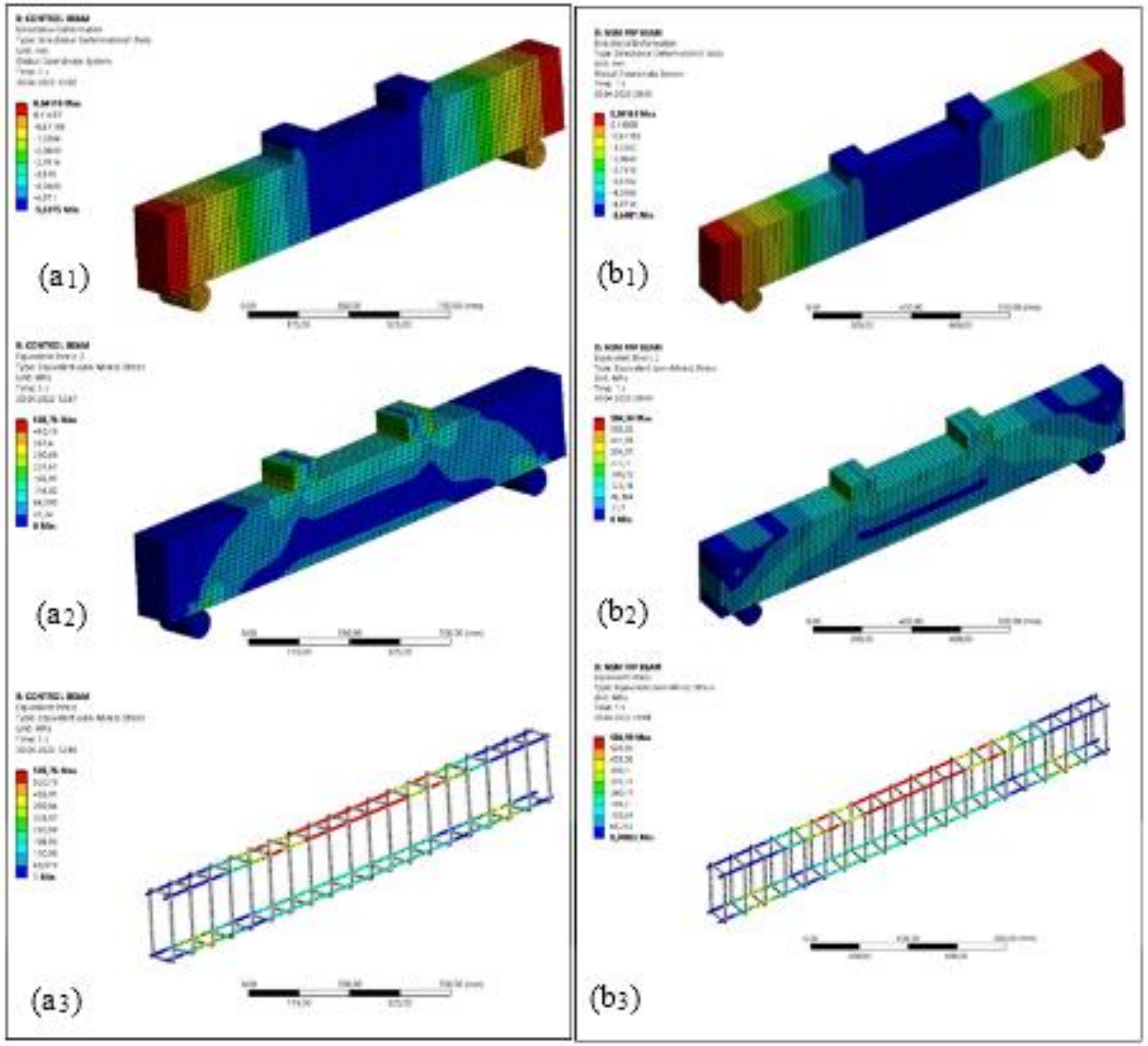

Fig. 3 The values of directional deformation and equivalent stress. (a_i) Control beam, (b_i) NSM FRP beam

4. Results

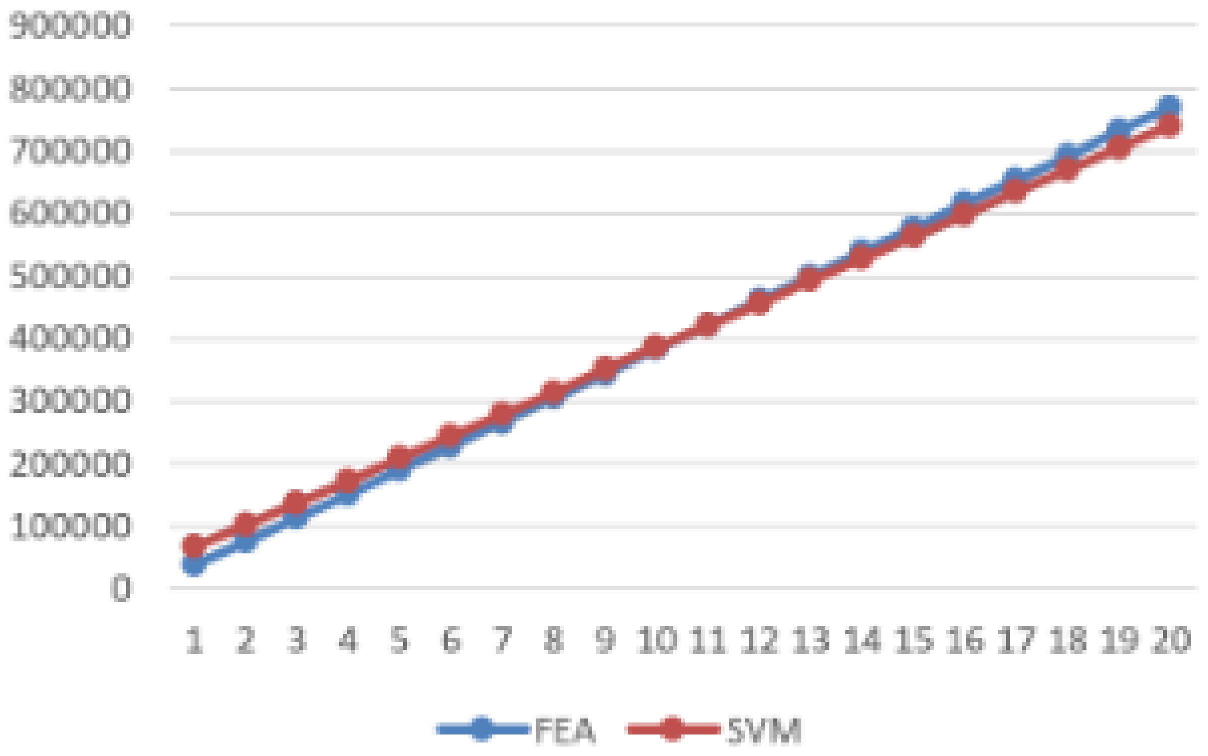

Fig. 4 The comparison of FEA vs. SVM

5. Conclusions

There are finite element studies on existing structural members. Computer modeling is becoming a more effective method to determine the behavior of structural members due to the studies need long time. The aim of study was to obtain results of a computer simulation that reflect the finite element analysis the behavior of NSM-FRP strengthened RC beams exposed to four-point bending. In this study, it is examined two types of RC beams including control beam, and RC beam with NSM-FRP using an FEA. Also, an ANN model was prepared. According to mechanical simulations and ANN results, the performance of beams which are retrofitted with NSM FRP can be evaluated through mechanical analysis in collaboration with an artificial intelligence approach.

Thank you