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Evaluation of RC Beam Performance with FEA and Linear Regression: A Comparative Study of RC Beam

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Scopes

1. Introduction
2. Materials and methods
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1. Introduction

In this study, Finite Element Analysis (FEA) was used to analyze reinforced concrete (RC) beams under static loadings. Through FEA, the performance of RC members was evaluated considering the stresses and strains emerging during the loading event. The results of the FEA simulation were then used to evaluate the structural integrity of the RC members and to identify potential design weaknesses. Different design parameters were employed, including the material properties of the RC members and the geometry of the members. In addition to FEA analyses, a linear regression approach was also performed to develop relationship between load and mechanical results. Overall, FEA was a valuable tool in understanding the behavior of RC members under various conditions and identifying potential design improvements as well as in constitution of input and output parameters regarding design of beams.

1. Introduction

Reinforced concrete (RC) beams are widely used in construction due to their high strength, durability, and flexibility in design. However, the seismic performance of RC beams is critical for ensuring the safety and resilience of structures in high seismic hazard regions. Finite element analysis (FEA) and linear regression are two commonly used methods for evaluating the seismic performance of RC beams. FEA is a powerful tool for analyzing the behavior of RC beams under seismic loading. It allows for the modeling of complex geometries and materials, and can capture the non-linear behavior of RC elements such as cracking, yielding, and failure.

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1. Introduction

Many studies have employed FEA to evaluate the seismic performance of RC beams, including their flexural and shear capacity, ductility, and damage evolution. For instance, Zhang et al. onducted a FEA-based investigation of the seismic performance of RC beams with various strengthening techniques, including external bonding of carbon fiber-reinforced polymer (CFRP) and steel plates. The study revealed that the use of CFRP and steel plates significantly enhanced the flexural and shear strength of the RC beams, and improved their ductility and energy dissipation capacity. Similarly, Joo and Kim performed nonlinear FEA to study the behavior of RC beams strengthened with externally bonded FRP sheets under cyclic loading. Linear regression analysis is a statistical method that has been used to develop predictive models for the flexural behavior of RC beams. Ghasemi et al. developed a linear regression model to predict the ultimate strength of RC beams based on their geometric and material properties. Babaei et al. [4] used linear regression analysis to develop a predictive model for the flexural behavior of RC beams based on the material properties of the concrete and steel reinforcement. Experimental testing is also an important method for studying the behavior of RC beams. Neves and Gomes (2017) conducted experimental and numerical studies to investigate the behavior of RC beams strengthened with carbon fiber-reinforced polymer (CFRP) laminates. Hong et al. performed numerical analysis on the shear behavior of RC beams strengthened with embedded glass fiber-reinforced polymer (GFRP) bars. Khan et al. used FEA to investigate the behavior of RC beams strengthened with FRP laminates under bending and shear loading.

1. Introduction

Although many researches have examined structural performance improvement through strengthening of RC beams, to the best of our knowledge, no studies have yet examined the structural performance of strengthened RC concrete with regression analysis the studies using numerical methods such FEA method and a linear regression approach to identify the relationship between RC beam structural parameters and to examine the structural performance of strengthened RC concrete are quite limited. Therefore, FEA models representing strengthened and non strengthened RC beams were created to obtain beam parameters and a regression analysis was conducted to determine the potential relationship in this study .

2. Materials and Methods

RC beam model was created based on the experimental studies to gain insight into structural behaviour. The model is mainly composed of reinforcement rebars, stirrups, concrete, bearing pads and supports. Reinforcement rebars consisting of two 8 mm and 12 mm in diameter bars were placed in the top and bottom of concrete geometry with a clear cover of 25 mm on all directions. The stirrups which is considered as a shear resistant reinforcement were designed to have a 10 mm diameter and placed at 100 mm intervals to avoid flexural failure of RC beam. Concrete body was modelled as a traditional casting concrete with 300×150×200 mm dimensions. Bearing pads and supports responsible for loading and fixture of the model body were located in consistent with the original experimental conditions. Model geometry was designed so that it allows simulation of a four-point bending and shown in Fig.1.

2. Materials and Methods

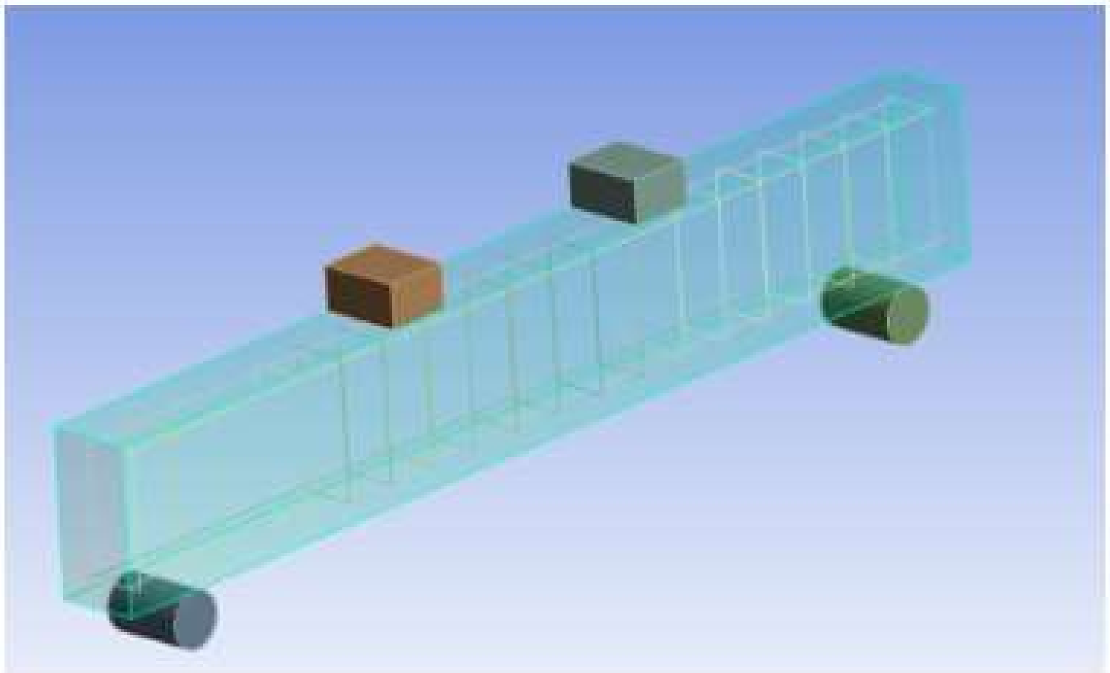

Fig. 1 General view of RC beam model

2. Materials and Methods

Material properties of RC beam components are influential on the mechanical response of the structure. Concrete was assumed to have a non-linear and isotropic behaviour whereas the reinforcement, bearing pads and supports were considered as linear, elastic and isotropic materials in FEA model. The details of RC beam materials are shown in the Table 1.

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Table 1. Material properties of RC beam components

Properties / Members	Concrete	Reinforcement	Bearing
Density (kg/mm^3)	2.4E-6	7.85E-6	1.83E-6
Young's modulus, E (MPa)	32000	200000	1440
Poisson's ratio, ν	0.2	0.3	0.4999
Tensile ultimate strength (MPa)	640.2	500	-
Compressive ultimate strength (MPa)	47.2	-	-
Tensile yield strength (MPa)	4.72	420	-

2. Materials and Methods

RC beam model was discretized with linear element order and 20 mm element size. Meshing the model provided 12000 elements and 14544 nodes in the geometry (Fig.2). Contacts between supports, concrete and bearing pads were assumed as bonded. During the simulations, the supports were fixed to avoid any translational movement. RC beam model was exposed to 5 mm displacement throughout the bearing pads.

FEA simulations were performed using to obtain the stress distribution on the concrete and reinforcement members as a result of loading. Vertical deflections especially at mid-span of concrete geometry was also aimed to examine. The element size and type in the model was selected to reduce the computational burden during the analyses.

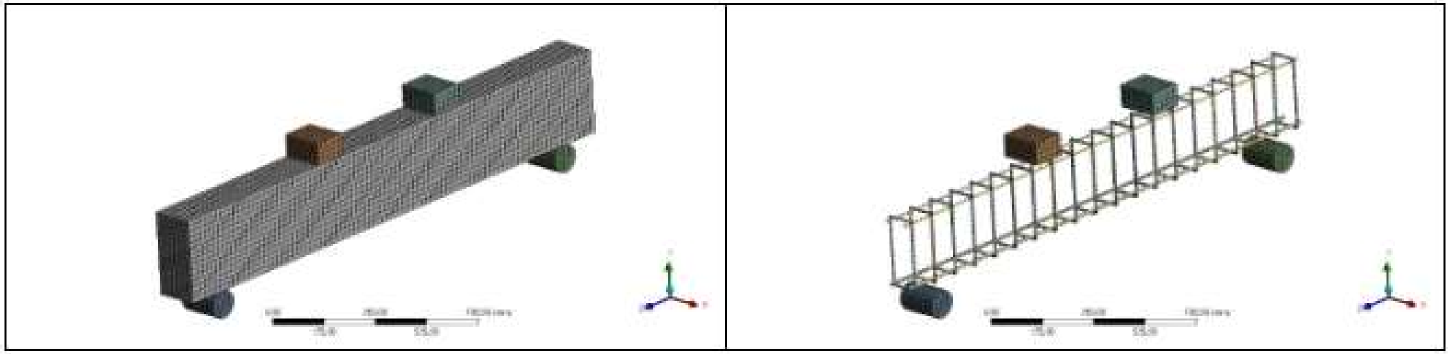

Fig. 2 Meshing the RC beam model

2. Materials and Methods

Regression is a statistical method that expresses the mathematical relationship between two or more variables with equations and reveals the way and size of the variables' effect from each other. Regression models are classified as linear and nonlinear models. In this study, linear regression was used and this model is defined by the following equation:

$$Y = \beta_0 + \beta_1 x$$

Y is the dependent variable, x is the independent variable, β_0 is the constant value of the equation and β_1 is the coefficient of the independent variable. Linear regression is a method that reveals the relationship between two variables with a linear model.

4. Results

As a result of the FE analysis, the deformation and stress values provided for 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 equation of regression is given in Eq.2. The values of RMSE error and $R2$ is found as 18,06 and 0,99 respectively.

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4. Results

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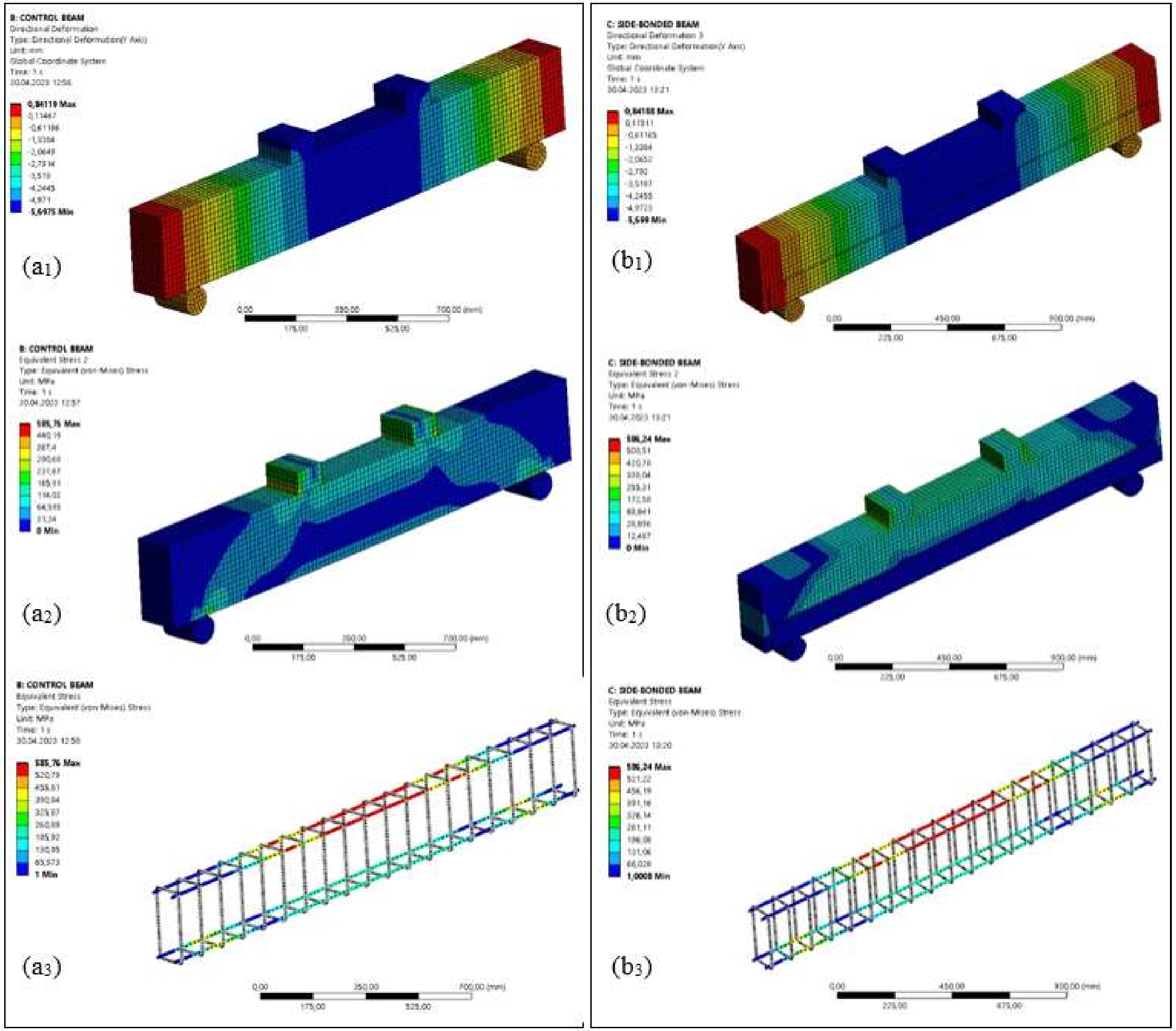

Fig. 3 The values of directional deformation and equivalent stress. (a_i) Control beam, (b_i) Externally bonded beam

4. Results

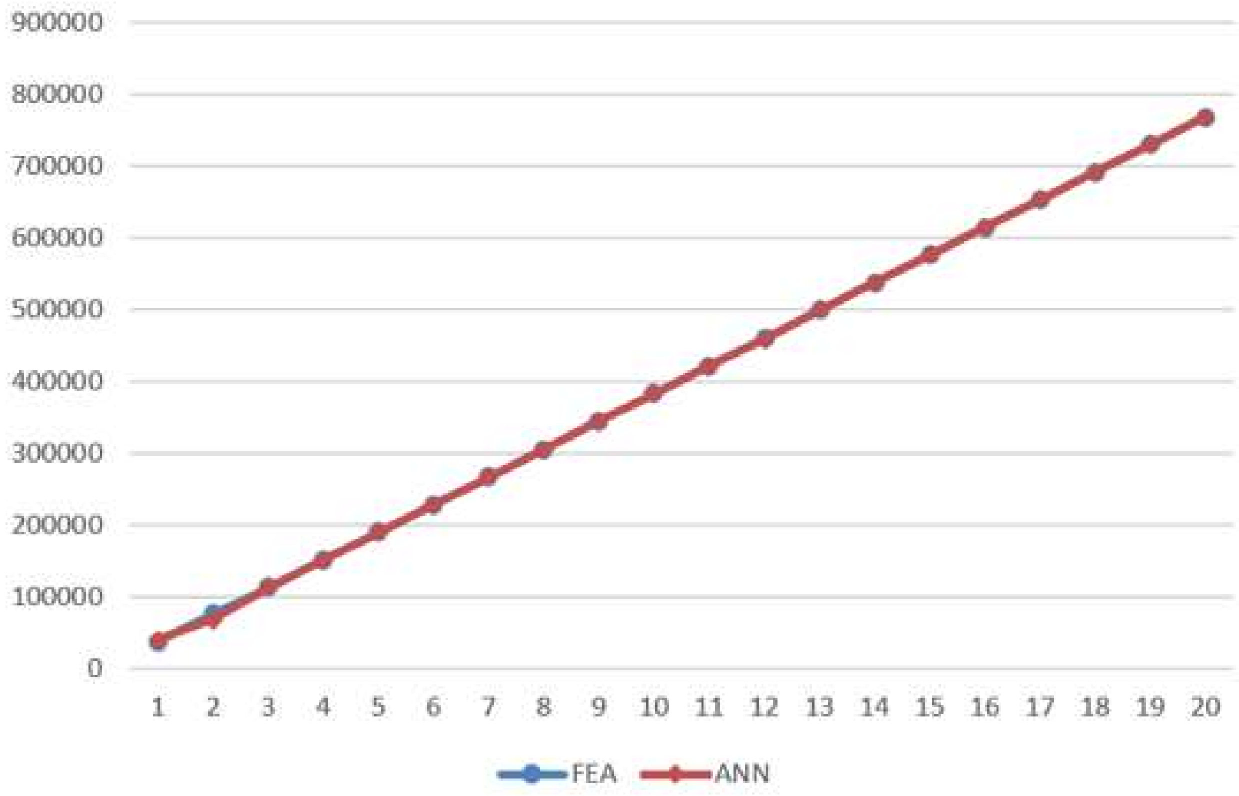

Fig. 4 The comparison of FEA vs. ANN

5. Conclusions

This study covers the FE Analysis to analyze reinforced concrete (RC) beams under static loading. The analysis results of the simulation were then used to evaluate the structural integrity of the RC structural models. In this study, various design parameters were employed. In addition to FE Analysis, a linear regression approach was also performed to develop relationship between load and mechanical results. It is concluded that FE Analysis was a valuable tool in understanding the behavior of RC members.

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5. Conclusions

Also, an ANN performance was allowed realistic predictions of RC beam strengthened with externally FRP. A FE analysis neural network modeling of RC beam are implemented in this study and their complementary has been presented in evaluation of design stage.

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Thank you