

Prediction of shear strength of steel fiber RC beams using neural networks

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Abstract

This paper presents the development of artificial neural network models for predicting the ultimate shear strength of steel fiber reinforced concrete (SFRC) beams. Two models are constructed using the experimental data from the literature and the results are compared with each other and with the formula proposed by Swamy et al. and Khuntia et al. It is found that the neural network model, with five input parameters, predicts the shear strength of beams more closely than the network with four input parameters. Moreover, the neural network models predict the shear strength of SFRC beams more accurately than the above-mentioned formulas. Further, the accuracy of predicted results is found not biased with concrete strength, shear span to depth ratio and the beam depth. Limited parametric studies show that the network model captures the RC beam's underlying shear behavior very well. © 2005 Elsevier Ltd. All rights reserved.

Keywords: Fiber reinforced concrete beams; Neural networks; SFRC beam; Shear strength

1. Introduction

Shear failure of a reinforced concrete (RC) beam occurs, when a diagonal crack forms and propagates through the beam web. Diagonal crack forms, when the principal tensile stress within the shear span exceeds the tensile strength of concrete. Use of randomly dispersed discrete steel or synthetic fibers into the concrete mix has found to increase the shear strength of beams significantly. Use of fibers is beneficial, since they are distributed throughout the concrete volume and provide equal resistance to stress in all direction, which is particularly advantageous in structures requiring to resist earthquake

and wind loading [1]. The addition of steel fibers in concrete has been found to improve the postcracking tensile strength of hardened concrete, and hence significantly enhances the shear strength of RC beams [2].

There have been a number of studies in the past, which confirm the effectiveness of steel fibers as shear reinforcement for RC beams [1–10]. Use of steel fibers relieves reinforcement congestion at critical sections such as beam–column joints. The use of fibers results in reduction of crack formation and their propagation, which enhances service load performance. Further, fibers are highly beneficial in thin and slender sections, where conventional stirrups are difficult to provide with. Another potential area of fiber use is in high strength concrete (with compressive strength of 50 MPa or higher). Though the use of high strength concrete is growing rapidly, it has demerits such as its relative brittleness and lack of ductility. This drawback can be overcome by inclusion of fibers in high-strength concrete mix [11].

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Nomenclature

a/d	shear span to effective depth ratio	ρ	longitudinal reinforcement ratio
α	arch action factor	σ_{pc}	postcracking tensile stress of concrete
b_w	beam width	τ	shear stress
β	factor for fiber shape and concrete type	v_c	concrete contribution to shear strength
d	effective depth of beam	v_{frc}	ultimate shear strength of SFRC beams
d_f	diameter of fiber	v_n	nominal shear strength
F_1	fiber factor	V_f	volume percentage of fibers
f'_c	compressive strength of concrete	V_n	shear force
l_f	length of fiber		

Over the years, several semi-empirical relations have been proposed to determine the ultimate shear strength of steel fiber reinforced concrete (SFRC, hereafter) beams. A number of formulas proposed by researchers, namely, Ashour et al., Li et al., Mansur et al., Narayanan and Darwish, Sharma, Shin et al. and Swamy et al. have been listed by Khuntia et al. [11]. Recently, Khuntia et al. [11] have proposed an equation to predict the shear strength of normal and high-strength concrete beams containing fibers in a unified manner and compared the accuracy of their equation with expressions by Narayanan and Darwish [6] and Swamy et al. [8].

As an alternative method, a neural network based model is developed in this paper using the data from the literature. Since neural network models are constructed from the actual experimental data, there is no need of any assumptions regarding the inherent physical behavior of SFRC beams. Neural network modeling technique has been successfully applied to many structural engineering problems, such as prediction of strength of concrete mix [12], prediction of shear strength of RC deep beams [13,14], modeling the capacity of pin-ended RC columns [15], structural damage assessment [16,17], modeling of material behavior [18], condition rating of concrete pavements [19] and structural analysis and design [20].

2. Research significance

Since neural networks have been found to be applicable to many complex problems in science and engineering, its application in prediction of shear strength of SFRC beams is an area to be explored. In this paper, two neural network models are developed for the prediction of shear strength of SFRC beams. The results are compared with each other and with the equations by Swamy et al. [8] and Khuntia et al. [11]. It is shown that the performance of the neural network models is accurate than these two equations, which can be applied satisfactorily within the range of parameters covered in the study.

3. Overview of neural network approach

Neural networks are an information processing techniques based on the way biological nervous systems, such as the brain, process information. The fundamental concept of neural networks is the structure of the information processing system. Composed of a large number of highly interconnected processing elements or neurons, a neural network system uses the human-like technique of learning by example to solve problems. The neural network is configured for a specific application, such as data classification or pattern recognition, through a learning process called training. Just as in biological systems, learning involves adjustments to the synaptic connections that exist between the neurons. Neural networks can differ on the way their neurons are connected; the specific kinds of computations their neurons do; the way they transmit patterns of activity throughout the network; and the way they learn including their learning fate. Neural networks are being applied to an increasing large number of real world problems. Their primary advantage is that they can solve problems that are too complex for conventional technologies; problems that do not have an algorithmic solution or for which an algorithmic solution is too complex to be defined.

The multilayer perceptron is the most widely used type of neural network. It is both simple and based on solid mathematical grounds. Input quantities are processed through successive layers of “neurons”. There is always an input layer, with a number of neurons equal to the number of variables of the problem, and an output layer, where the perceptron response is made available, with a number of neurons equal to the desired number of quantities computed from the inputs. The layers in between are called “hidden” layers. With no hidden layer, the perceptron can only perform linear tasks. All problems, which can be solved by a perceptron can be solved with only one hidden layer, but it is sometimes more efficient to use two hidden layers. Each neuron of a layer other than the input layer computes first a linear combination of the outputs of the neurons of the

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