PREDICTION OF SHEAR BEHAVIOR OF FIBER REINFORCED CONCRETE BEAMS USING NEURAL NETWORKS

By

Shaimaa Abd El-Tawab Mohamed

B.Sc. in Civil Engineering
Cairo University

A Thesis Submitted to the
Faculty of Engineering, Cairo University
In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE
IN
STRUCTURAL ENGINEERING

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Dedication

To Ethics Establishers, My Parents

To supporter, My Husband

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Abstract

As a matter of fact, there are many parameters that have the influence on the shear strength in fiber reinforced concrete (FRC) and there is a lack of thorough understanding of the various force-resisting mechanisms acting in a beam prior to ultimate load. So, these factors lead to the complexity of analytical prediction of shear strength. In other words, it has been very difficult to create a general simple formula for predicting the shear strength of FRC beams. In addition to the absence of clear equations in the building codes that explain shear strength for FRC beams. Therefore; there has been a need to develop a numerical approach that can be used to predict shear behavior in fiber reinforced concrete (FRC).

The main objective of this research is to develop an artificial Neural Network that is able to predict shear strength and simplify its use through developing a Graphic User Interface (GUI). Moreover, shear behavior in fiber reinforced concrete beams (FRCBs) is quantified by compressive strength of concrete, longitudinal steel, size effect, fiber's type, content and aspect ratio.

The research methodology is based on collecting experimental results of technical investigations carried out so as to predict shear behavior in FRCBs. An artificial neural network aims at reducing the amount of computing time required in the numerous iterations involving structural analysis and experimental work. For this, two back-propagation neural networks have been experimented by MATLAB program; their types have been fitting (1^{st} network) and pattern recognition (2^{nd} network) which have been used to classify failure of FRC beams into 6 categories. Through simulation study, the optimum architectures for the individual NNs have been determined. The training algorithms use feed forward back propagation. The ANNs model has been assessed in comparison with exact values and deduces a good correlation with it.

Finally a software program is developed in order to be used as an evaluation system for resistance of FRC beams to shear forces, and also to expect the failure pattern in order to avoid its occurrence.

Chapter 1

1 INTRODUCTION

1.1 GENERAL

The major and primary industrial encouragement in using fibers at concrete structures is to reduce time and cost of construction. This trend appears especially in an era of high labor costs and possibly even labor shortages, since conventional stirrups require relatively high labor input to bend and fix in place.

Previous studies that have been carried out for structural applications of fiber reinforced concrete have included slender and deep beams with or without transverse reinforcement, ductile beam-column connections and flat-plate slabs subject to punching shear. Moreover, many reports which have been published over the past 25 years have confirming the effectiveness of fibers in reinforced concrete as shear reinforcement.

Fibers are generally used to:

- Increase the shear capacity of concrete or to replace, in part, the vertical stirrups in RC structural members, a matter that will relieve reinforced congestion at critical sections such as beam-column junctions.
- Be easily placed in thin or irregular shaped sections, such as architectural panels, where it may be very difficult to place stirrups.
- In high strength concrete, which grows rapidly, fibers are attractive for longer spans and taller structures, as well as for earthquake resistant structures of any size where a reduction of mass is very important. Therefore, the application of high-strength concrete is hindered by its relative brittleness and lack of ductility. This drawback can be overcome by inclusion of fibers in high-strength concrete mix.

1.2 PROBLEM STATEMENT

Shear strength in fiber reinforced concrete beams (FRCBs) is affected by dimensions of beams, compressive strength of concrete, amount of longitudinal steel, stirrups existence, fiber's type, content, and aspect ratio in addition to physical factors as: aggregates interlock, dowel action…etc. These factors have created a difficulty in dealing with shear behavior and the estimation of shear capacity.

In the literature, each research has focused on certain parameters affecting shear behavior and derived an empirical equation for the estimation of shear strength.

So, to mitigate the hazards of structural failures due to shear forces and to reduce construction time and cost, the need of predictive system that can predict shear strength for fiber reinforced concrete beams and their expected modes of failure has been required.

1.3 OBJECTIVES

In order to realize previously mentioned aims and solve inherent problems, the main objectives of this research work have been specified as follows:

- Review the state of the art shear strength on reinforced concrete beams by the way of using both steel and synthetic fibers as shear reinforcement with and without stirrups.
- Review the state of the art types of fibers, benefits and problems.
- Review the literature of artificial neural networks and other computerized evaluation techniques so as to predict shear strength in fiber reinforced concrete beams.
- Develop an Artificial Neural Network (ANN) to be able to predict and evaluate shear strength in fiber reinforced concrete beams in addition to their failure patterns. Furthermore; Shear strength in fiber reinforced concrete beams has relied on concrete compressive strength, beam size, longitudinal reinforcement, fiber type and content.
- Create Graphic User Interface (GUI) for the developed ANN that can simplify its use. The GUI along with the developed ANN constitutes a package that can be used in health monitoring of similar beams.
- Compare the effect of various factors on the shear strength.

1.4 OUTLINE of the THESIS

Chapter one includes a brief introduction to the thesis.

Chapter two includes the literature review of the research, also discussions on the usage of fibers in concrete structures, shear strength in fiber reinforced concrete beams and modes of failure are included, and also an overview of artificial neural networks (ANNs) has been included, too.

Chapter three introduces definitions for the work data and its limits.

Chapter four has dealt with the neural network model design including identification method for input parameters and the performance of model neural network architectures.

Chapter five includes GUI verification and explanation, display screens of the program, verification examples and parametric study.

Chapter six indicates a summary, conclusions and recommendations for possible future effort.

Appendix (A) includes a program code for artificial neural network using MATLAB Guide.

Chapter 2

2 LITERATURE REVIEW

2.1 OBJECTIVE

An overview on shear strength of fiber reinforced concrete beams and the factors that have an effect on them, modes of failure at FRC beams have been included in this chapter. In addition, artificial neural network has also been discussed.

2.2 FIBERS

2.2.1 Background of Fiber Reinforced Concrete (FRC)

According to (R. Brown) [1], "FRC is Portland cement concrete reinforced with more or less randomly distributed fibers. In FRC, thousands of small fibers are discrete and distributed randomly in the concrete while being mixed, and thus improve concrete properties in all directions. Fibers help to develop the post peak ductility performance, pre-crack tensile strength, fatigue strength, impact strength and eliminate temperature and shrinkage cracks."

Fibers made of steel, plastic, glass, and natural materials (such as wood cellulose) have existed in different shapes, sizes, and thicknesses; they have representative lengths of 6 mm to 150 mm (0.25 in. to 6 in.) and thicknesses ranging from 0.005 mm to 0.75 mm (0.0002 in. to 0.03 in.). Also, they may be of forms as round, flat, crimped, and deformed. They are added to concrete during mixing (CME302) [2]. The main factors that dominate the performance of the composite material are physical properties of fibers and matrix and strength of bond among them.

2.2.2 Types of Fibers

2.2.2.1 Steel Fibers

According to (ELsaigh) [3], "There are a number of different types of steel fibers with different commercial names. Basically, steel fibers can be categorized into four groups depending on the industrialized process as; cut wire (cold drawn), slit sheet, melt extract and mill cut."

They are short, discrete lengths of steel with an aspect ratio (ratio of length to diameter) from about 20 to100 and with any of the numerous cross sections. Some steel fibers have hooked ends to improve resistance for a purpose of being pullout from a cement-based matrix (CME302) [2].

Also, (Nataraja) [4] said that Carbon steels are most commonly used to produce fibers, but fibers made from corrosion-resistant alloys are available. Stainless steel fibers have been used for high-temperature applications. Some fibers are collated into bundles using water-soluble glue to facilitate handling and mixing.

In general, SFRC is very ductile and particularly well suited for structures which are required to exhibit: