AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

USE OF ARTIFICIAL NEURAL NETWORK IN HIGH PERFORMANCE CONCRETE STRUCTURAL APPLICATIONS

by
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STATEMENT

This dissertation is submitted to Ain Shams University to fulfill the requirements of the degree of Master of Science in Structural Engineering. The work included in this thesis has been carried out by the author - in the Department of Structural Engineering, Ain Shams University - from October 2007 to January 2016. No part of this thesis has been submitted for a degree or a qualification at any other university or institution.

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USE OF ARTIFICIAL NEURAL NETWORK IN HIGH PERFORMANCE CONCRETE STRUCTURAL APPLICATIONS

SUMMARY

High performance Concrete (HPC) is known as a high technology construction material, proving to be very cost effective, reliable, and having long term durability in natural environment. Designers are termed upon to design slimmer, lighter structures with high load carrying capacities. These slimmer structures are much more disposed to punching shear failures, especially in the area of column/slab connections.

Reinforced concrete plates exhibit complexities – most importantly punching shear - in their structural behaviour. This is due to the composite nature of the materials and factors affecting such behavior. Unanimous agreement states that the factors of most significant effect – for the overall punching shear capacity - are namely concrete compressive strength f_{cu}, flexural reinforcement ratio ρ and its yielding strength f_y, effective slab depth d, and the effective perimeter b_o (a function of the column geometry and slab depth). Concrete compressive strength, however, is the most prominent of the above. Researchers have emphasized on the usage of high performance concrete HPC– particularly high strength concrete HSC – to observe its effect on the punching shear capacity of the slab-column connections.

In this regards, a thorough literature review was conducted on the punching shear phenomenon in slab-column connections and influencing factors. A total of 495 punching shear sample results were collected from a diversity of research studies. In this study, the data-set is used to compare the already existing major formulas in international codes as well as research

efforts; predominantly; based on empirical equations. The coefficients of these models are thus re-calibrated (optimized using the Matlab optimization toolbox); giving – in certain cases – a significant enhancement to the model performance. A new empirical (optimization-based) equation is proposed, yielding excellent performance (minimum sum square error); considering the 495 samples.

Furthermore, an Artificial Neural Network (ANN) model is developed using the collected data. The results obtained show high proximity to experimental output punching shear capacity results. Results on the ANN model are finally compared to the punching shear capacity of the proposed model that gave the best results after coefficient recalibration. This thesis also includes a parametric study for the punching shear input parameters and their significance as regards the output punching shear capacity of the slab-column interior connections.

Keywords: High Performance Concrete; Punching Shear Capacity, Shear Strength, Modelling, Optimization, Artificial Neural Networks (ANN)

To fulfil the previously mentioned objectives, this research is divided into the following chapters:

- ***Chapter One:*** includes the background and problem definition of the thesis, research objectives, scope and contents, and thesis structure.
- ***Chapter Two:*** covers the punching shear phenomena in flat plates and the major parameters affecting the shear strength, as well as using HPC/HSC in enhancing the punching shear. The earlier researches in punching shear applying artificial neural networks (ANN) was displayed.

- ***Chapter Three*:** covers the details of the collected experimental test results.
- ***Chapter Four*:** discusses the main variables affecting punching shear strength are (i) concrete compressive strength, (ii) grade of flexural reinforcement, (iii) ratio of flexural reinforcement, (iv) average effective slab depth and (v) column size. This chapter demonstrates an elaborate comparison between all available models/formulas made available; whether in codes, guidelines or previous research studies. The extensive dataset - of 495 samples - shown in Chapter 3 is used as means of comparison; wherein the main comparison criteria is the "Normal Root Mean Square Error" (NRMSE); a function of the "Sum of Square of Residuals" (SSR). The model/formula yielding the minimum NRMSE – and in turn minimum SSR between the punching shear strength of the model and that of the experimental output – is deemed to give the best fit amongst all other models. In light of the available data-set a recalibration of coefficients has taken place using the Matlab optimization toolbox. Another comparison is performed between the performance of each model before and after calibration. It also provides analysis of the available results. Development of a comprehensive tool (program) for the prediction of punching shear of flat plates using the conducted ANN model induced.
- ***Chapter Five*:** includes the thesis summary and presents the main conclusions that could be drawn from the current work. Prospects for further research as an extension to the results obtained from this thesis are given at the end of this chapter.

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