Assessment of Cracks in Reinforced Concrete Beams Using Artificial Intelligence Techniques

By

Ahmed Ayman Ahmed Shaheen

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfilment of the
Requirements for the Degree of
DOCTORATE OF PHILOSOPHY
In
STRUCTURAL ENGINEERING

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Crack detection, image processing, image-base analysis, Artificial Neural Network, Expert Systems

Summary:
Several techniques have been introduced to detect cracks and damages in concrete elements. Current practices of evaluating damages in concrete elements are costly and time consuming. This research presents a framework that utilizes artificial intelligence techniques to recognize cracks in reinforced concrete beams. The framework consists of three main components; Image Processing tool, Neural Network models, and Expert System model. Image processing tool utilizes percolation to identify the presence of the structure element and crack map. Then, Red-Green-Blue (RGB) to grayscale and to binary image conversion and filtering algorithms are applied to get a topological crack map. Many aspects are acquired such as coordinates, angels, diagonal, and Total Area of Crack Percentage (TACP) in order to identify geometric properties for both beam element and crack map. Graphical properties including length and orientation are extracted and mapped on the beam element to produce relative measurements and then to crack type recognition. Crack types are predicted using back propagation neural network model. Neural Network model receives geometric properties as an input and produces crack type identification as an output. The expert system model enhances ways of maintenance and rehabilitation. It utilizes the crack type (generated from neural network model) and TACP in order to provide the suitable repair method. Real images for two defected beams are used to validate the proposed framework and to compare its output to manually identified cracks and applied repair method. The results reveal the framework recommended solutions are in compliance with these that have been applied in reality.

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To my beloved wife I dedicate this dissertation.

Ahmed Ayman Shaheen, March 2018

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ABSTRACT

Several techniques have been introduced to detect cracks and damages in concrete elements. Current practices of evaluating damages in concrete elements are costly and time consuming. Limited research efforts have focused on automating the process of retrieving damage properties in concrete elements. It is worth noting that choosing a proper repair depends mainly on the causes of defects. This research presents a framework that utilizes artificial intelligence techniques to recognize cracks in reinforced concrete beams. The framework consists of three main components; an Image Processing tool, a Neural Network models, and an Expert System model. Image processing tool utilizes percolation to identify the presence of the structure element and crack map. Then, Red-Green-Blue (RGB) to grayscale and to binary image conversion and filtering algorithms are applied to get a topological crack map. Many aspects are acquired such as coordinates, angels, diagonal, and Total Area of Crack Percentage (TACP) in order to identify geometric properties for both beam element and crack map. Graphical properties including length and orientation are extracted and mapped on the beam element to produce relative measurements and then to crack type recognition. Crack types are predicted using back propagation neural network model. Neural Network model receives geometric properties (extracted by image processing) as an input and produces crack type identification as an output. The expert system model enhances ways of maintenance and rehabilitation. It utilizes the crack type (generated from neural network model) and TACP in order to provide the suitable repair method. Real images for two defected beams are used to validate the proposed framework and to compare its output to manually identified cracks and applied repair method. The results reveal the framework recommended solutions are in compliance with these that have been applied in reality.

CHAPTER 1

INTRODUCTION

1.1 General

Buildings are one of the most precious productions built by human. Construction engineers give great attention to keep structure elements of buildings safe and serviceable. So, there should be efficient tools available with specialists to keep up with requirements and technology rates. One of the most deterioration states that occur in concrete structures is cracking. Hundreds of buildings are subjected to cracks due to unusual structure attacks or even by erosion. Therefore, it is important to introduce a framework that can be used as a tool to support decision towards cracking.

1.2 Problem statement

The safety of defected beams is usually evaluated manually by structural specialists (e.g. structural engineers and/or certified inspectors) they follow the guidelines provided by the applicable specifications and codes, in which they ensure that the defected components remains stable and maintains a specific level of structural integrity. A whole building safety evaluation may take several weeks due to the large number of elements (slabs, beams, columns, and footings) required to be assessed. The aforementioned limitations can be overcome if the current manual evaluation practices are fully or partially automated. This requires that damages lying on structural member surfaces not only be detected, but also to be assessed based on their properties. So far, many machine vision based methods have been created to locate the damage on structural member surfaces, and their effectiveness has been validated in inspecting structures such as bridges, pipes and tunnels. On contrast, little work was found regarding how to automatically retrieve useful damage properties from detection results and further apply these properties to estimate the damage state of structural members.

Concrete structure experts confirm that putting hand on the deterioration reason is essential to choose proper way of repair especially when the defected element is a structural one; that resists combination sorts of straining actions (i.e., normal forces, shear forces, flexure, etc). Each action (whenever it reaches a limit of a section's capacity, or even element's material reached inadequate state) shows a type of deterioration different than other types. These types could be detected and recognized by an expert visual inspection, and then the inspector may recommend a maintenance or rehabilitation method depending on his opinion.

These ideas led to steer the research towards finding the way that enables the expert recognizing crack type. It is found that geometric characteristics of cracks are the right way to do that. However, limited research efforts discuss geometric characteristics of concrete cracks.

Even after crack type is recognized, decision by an expert will stay incomplete till he/she deduces the element impairment extent. In other words; according to the degree of deterioration the element reaches the expert choose between maintenance and rehabilitation. Choosing between maintenance and rehabilitation leads to an economic impact. So, the decision maker considers the feasibility of repair. However, the impairment state may guide the expert that the element is about to fail and rehabilitation