Applications of Artificial Intelligent Systems in Bridge Engineering

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ABSTRACT

Condition assessment of reinforced concrete bridges is a complex subject imbued with uncertainty and vagueness. This complexity arises from numbers and relations of different kind of problems in reinforced concrete bridges. Condition assessment requires vast knowledge of the behaviour of reinforced concrete structures subjected to different phenomena such as excessive loading, environmental effects and chemical attacks. This requirement can be achieved through an expert system, which may represent human expertise. This study present an Artificial Neural Network (ANN) assisted crack rating system for RC bridges' girder which improves the effectiveness of crack condition rating. The ANN system was developed as an alternative to traditional crack rating methods. The rules for the ANN system were constructed from expert knowledge, technical books and inspection results of 5 different RC bridges. The results obtained by ANN model show high correctness ratio conformity to crack rating obtained by the traditional inspection methods.

INTRODUCTION

In recent years the public and the government have been major driving force in reinforced concrete bridges along highways. As a result there has been a rapidly accelerating trend towards conditional assessment and solution to reinforced concrete bridge problems. For example, in United State FHWA (Federal Highway Administration) indicates that investment was as much as $1 billion annually for R.C Bridge deck rehabilitation [1]. Condition assessment process requires deep knowledge of the behaviour of reinforced concrete bridges, awareness of changes, good understanding of design process and most importantly, and skilful personnel. Successful solution to overcome this obstacle is the use of computer-assisted tools such as expert systems.

Computer-assisted tools have been practicing in civil engineering field successfully in advanced level. The expert system is used to aid in making recommendations, allow an expert to concentrate on more difficult aspects of the task, enforce consistency, perform dangerous tasks which would otherwise be carried out by humans, preserve valuable knowledge which would otherwise be lost when an expert is no longer available[2].

Intelligent system successfully applied on structural size and cost optimization problems. [3-9] Mathematical optimization method on the preliminary design stage of precast member have been practicing by many companies [10].Detailed reviews and the most significant examples of their application in civil engineering field can be found in literature [11].

The large number of articles on neural network applications in civil and structural engineering shows that the technology proved its importance for the civil and structural engineering field. Bridge management and ratings are another area in which engineers have been successfully applying the intelligent systems of neural networks [12-21]; the system was trained and used successfully in estimating a rating based on bridge parameters by J. Cattan [22].

Mikami [23] has developed a knowledge-based system for selection of the methods for retrofitting fatigue cracking in steel bridges by using an expert system shell. An expert system for risk assessment of concrete dams, which has been developed by Bruno in 1999 [24], can be considered as a good example of an expert system application in Civil Engineering field. The general structure of the system constructed in an inference tree which organizes both the description of the knowledge and the procedures that control this knowledge to perform an effective risk assessment.

This research is aimed to develop an engineering decision – making tool to assist an inspector during the inspection of crack on bridge members that may lead to the enhancement of bridge safety.

METHODS

A numerical rating system (Table 1) ranging from 1 to 5 is assigned to cracks based on the observed crack level and the resulting effect of the cracks on the structure ability to perform its indented function. The rating is achieved as final products of the AAN system in the study and represents the risk level of the crack.

Rating	General Definition
5	Being heavily and critically damaged and possibly affecting the safety, it is necessary to implement urgent repair or strengthening work. A detailed inspection should be carried out **(Very High Risk)**
4	Crack detected is critical and thus it is necessary to implement repair work. A detailed inspection should be carried out to determine whether any rehabilitation work is required or not **(High Risk)**
3	Damage detected is slightly critical and it is necessary to carry out routine maintenance work**. (Medium Risk).**
2	Crack detected and no maintenance required. It is necessary to record the condition for observation purposes **(Low Risk).**
1	Crack detected and it is necessary to record the condition for observation purposes. **(No Risk).**

Table 1 Definition of Crack Ratings

The type of crack (shear or flexural), Location, Temperature changes ,Crack width, crack length, crack depth, shape of crack and associates distresses with cracks were used as inputs for the ANN model which was performed by Satistica software program. Input data were selected based on expert knowledge and technical books. Most of the cracks that appear on RC bridges' girder are occurring because of plastic shrinkage, plastic settlement, constraint early thermal movement, constraint early drying shrinkage movement, support settlements, over load, bad design and bad detailing. The factors considered as inputs for RC bridge crack rating presents at Table 2.

Crack Properties	Extent	Code
Shape of crack	Random Crack	1
	Vertical crack	2
	Along Steel Mesh	3
	Diagonal Crack	4
Shear and Flexurality	Not clear	1
	Shear Appearance	2
	Flexural - Shear Appearance	3
	Flexural Appearance	4
Location of Crack	Does it appear in localized region	1
	Abrupt changes in section	2
	Right angle to the direction of wind	3
Temperature changes	High >20 ^{o}C	1
	Normal <20 ^{o}C	2
Loading	Heavy Loading	1
	Average Loading	2
Width of crack	0.1mm to 0.3mm	1
	0.3mm to 1.0mm	2
	1.0mm to 2 mm	3
	2 mm to 3.5 mm	4
	above 3.5	5
Time After construction	less than 7 days	1
	2 weeks to 4 weeks	2
	After 4 weeks	3
Length of crack	Crack length / member size 1- 20%	1
	Crack length / member size 21 -40 %	2
	Crack length / member size 41 -60 %	3
	Crack length / member size 61 -80 %	4
	Crack length / member size 80-100 %	5
Depth of crack / effective depth	0-0.3	1
	0.31-0.7	2
	0.71-0.95	3
	0.96-1.5	4
	1.51-1.9	5
	1.91-3.00	6
Associates	None	1
	Different settlement of the supports	2
	Deformation occur in the concrete member	3
	Rust colored corrosion cracks	4
	Expose reinforcement	5

Table 2

The factors considered as input for RC bridge crack assessment

A total of 750 data sets were separated into the training and test sets. Seventy-five percent of data sets were used for training the network, while the remaining 25% was used for testing. In the ANN model, the cases were altered randomly among the training and test subsets. The networks for modelling were trained using different numbers of neurons, numbers of hidden layers, activation functions and training algorithms. The linear hyperbolic activation function and the back propagation training algorithm were used in the presented model.

RESULTS

Five reinforced concrete bridges’ cracks were inspected to obtain real cracks inputs for the ANN model. Bridges have different ages, lengths and span number. All crack details were carefully recorded to use as input data to evaluate the proposed model. Existing crack rating and properties of bridge were tabulated at Table 2.

Table 2 Inspected bridges and crack ratings

No	BridgeName	Age	Material	Span Number	Length (m)	Cracks Rating Inspection	Crack Rating ANN
1	MbiklaimiH. Vore	22	RC	18	320	5	5
2	Ura eKucit	40	RC	5	60	5	5
3	Ura e Popcishtit	40	RC	1	18	5	5
4	Ura e Babanit	45	RC	5	60	3	4
5	Ura e Kamzes	35	RC	7	140	3	4

Affect of visual inspection data such as Size of crack: width, length and depth; Shape of Crack: random crack, vertical crack, along steel mesh, diagonal crack, shear crack, flexural; Location; Appearance time; Environment temperature change; Loads type last but not least Associates: Expose reinforcement, Rust coloured corrosion cracks, Deformation occur in the concrete member and Different settlement of the supports were investigated to achieve a model to represent the rating. Model inputs are listed at Table 3 with ANN output of rating of crack. The output is tabulated in the same table at rating column. The knowledge for analyzing rating of cracks is implemented in the computer as the neural network as shown in Fig. 1.

Table 3 Inputs of the proposed ANN model.

Crack No.	Shape of c.	Shear and flexural	Location of crack	Time	Tem.	Loading	Width of crack	Length of crack	Depth of crack	Associates	Rating
1	4	2	1	3	1	2	5	1	3	2	5
2	4	2	1	3	1	2	3	4	4	5	5
3	2	4	1	3	1	1	5	4	5	3	5
4	4	4	1	3	1	1	4	4	3	2	4
5	3	1	2	1	2	2	4	3	4	4	4

Appearance time of the cracks is found to be the most influence factor on the rating system. This is followed by associates. The model shows acceptable correction as shown at last two columns of Table 2. Results are quite similar with crack rating obtained by the traditional inspection methods by experts.

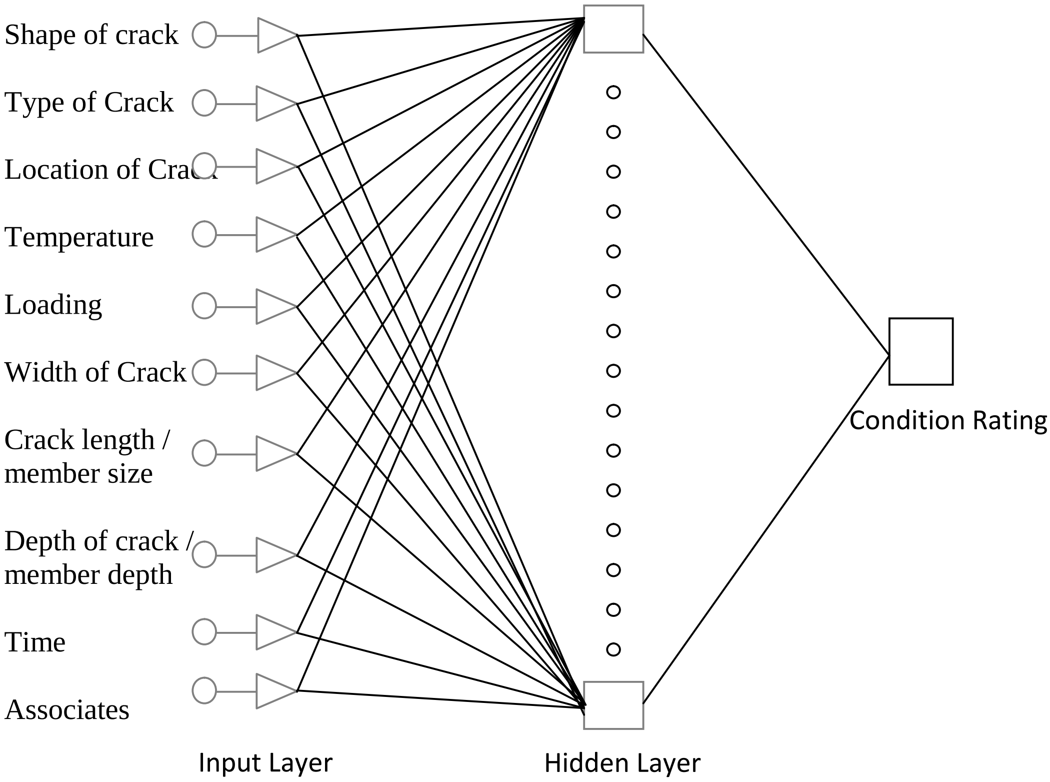

Figure 1 Artificial Neural Network Architecture

CONCLUSIONS

This study present an Artificial Neural Network (ANN) assisted crack rating system for RC bridges' girder which improves the effectiveness of crack condition rating. The ANN system was developed as an alternative to traditional crack rating methods. The rules for the ANN system were constructed from expert knowledge, technical books and inspection results of 5 different RC bridges. A high-precision model was constructed using ANN for predicting the crack rating which contribute to decreasing many uncertainties in RC bridge assessment and improving the effectiveness of crack condition rating. It is concluded that this ANN model can be used for predicting the crack rating of cracks on RC bridges girder.

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