

Fuzzy Mathematics based Bridge Deck Damage Detection Analysis

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Abstract

Bridges are an indispensable part of modern transportation, of which the bridge deck is one of the most important parts to carry traffic loads. Therefore, damage detection analysis of bridge decks is essential to maintain the safety of bridges. In this paper, a bridge deck damage detection analysis method based on fuzzy mathematics is proposed. This method uses fuzzy mathematical theory to model and analyze the damage state of the bridge deck, and then realize the damage detection method. This method uses fuzzy mathematical theory to model and analyze the damage state of the bridge deck, and then realize the damage detection of the bridge deck. This method uses fuzzy mathematical theory to model and analyze the damage state of the bridge deck, and then realize the damage detection of the bridge deck.

Keywords

Bridge; Bridge Deck; Damage Detection; Fuzzy Math.

1. Introduction

Bridges are an indispensable part of modern transportation, but as they are used for a longer period of time, the damage of bridges will become more and more serious, which will directly jeopardize the safety of pedestrians and vehicles. Therefore, the detection and analysis of bridge damage is particularly important and urgent. Among them, the bridge deck is the main part of the bridge that carries traffic loads, and its damage state directly affects the safety and service life of the bridge. The traditional bridge deck damage detection method mainly relies on the opinions and feelings of professionals, which has the problems of large subjectivity in judgment, low accuracy and susceptibility to external interference. For this reason, this paper proposes a fuzzy mathematics-based bridge deck damage detection and analysis method, aiming to improve the efficiency and safety of bridge maintenance.

2. The Importance of Bridge Safety Assessment

2.1 Formulation of the Problem

Bridges are hub projects in the transportation system, an important part of lifeline projects, and play a pivotal role in the national economy and social life as important national infrastructure. With the continuous prolongation of the service life of bridges, countries around the world are increasingly concerned about the safety of bridge structures in service, and the evaluation of bridges has become an urgent field to be strengthened in bridge engineering research. Reasonable evaluation of the safety of bridges is an urgent topic of great engineering significance.

After a bridge is built and enters service, with the passage of time, the continuous increase of traffic volume and the increase of vehicle load, under the action of unfavorable factors in the natural environment, the bridge structure will undergo damage and material aging, resulting in the aggravation of functional defects of in-service bridges in terms of traffic capacity and load-bearing

capacity, and the decline of bridge safety, which will affect the safety of transportation and even lead to the occurrence of accidents of bridge destruction and human deaths. In the United Kingdom, more than 90% of the bridges built after 1955, the design life of 120 years, but in less than 1/4 of the design life of the use of time, it was found that most of the bridges need to be repaired. The problem is also significant in the United States, where more than 45% of the 580,000 bridges on the U.S. highway system are considered to be deteriorating or have insufficient load-carrying capacity, and \$91 billion was spent in 1991 to rehabilitate bridges damaged due to durability deficiencies. The Sungsu Bridge in South Korea suffered a major accident in 1994 when the central section collapsed by 50 metres, 15 metres of which fell into the river, killing 32 people and seriously injuring 17.

At present, the many problems of in-service bridges have attracted extensive attention from the bridge community and have gradually become a key area for the development of civil engineering structures and bridge engineering analysis research.[1,2] The problems of in-service bridges have attracted much attention from the bridge community and have gradually become a key area of research and development in the analysis of civil engineering structures and bridge engineering. However, due to the lack of bridge design and construction quality, the general insufficiency of load-bearing level of bridges constructed in the early period, the natural damage during the use of bridges, the aggravation of structural damage caused by overloading, and the role of natural disasters, the safety and normal use of bridges in service have been seriously affected. Therefore, in order to ensure the safety of in-service bridges during the service period, and as an important basis for repair and reinforcement to ensure the normal use of bridges, it is necessary to further explore and study the technical methods of safety assessment of in-service bridges.

3. Bridge Deck Damage Detection Methods

3.1 Fuzzy Mathematical Theory

Fuzzy mathematics is a theory that uses mathematical methods to model and study uncertainty. In layman's terms, it is the transformation of uncertain information into a mathematical model by means of fuzzification, so that it can be analyzed and processed. The main characteristic of fuzzy mathematics is its ability to deal with inexactness, vagueness, incompleteness and multiplicity. In the analysis of bridge deck damage detection, fuzzy mathematical theory has better applicability and accuracy due to the complexity and diversity of the actual situation.

3.2 Modeling of Bridge Deck Damage State

In modeling the damage state of bridge deck slabs, it is first necessary to determine the degree and location of the damaged bridge deck slabs. Then, the bridge deck damage state is modeled by determining a certain division interval, establishing the affiliation function and determining the fuzzy degree function of the damage state. Finally, the fuzzy comprehensive evaluation method is used to evaluate and analyze the damage state of the bridge deck to achieve the purpose of detecting the damage of the bridge deck. Specifically, the bridge deck damage state model can be expressed as follows:

$$U = \{(F_1, \mu_1), (F_2, \mu_2), \dots, (F_n, \mu_n)\}$$

Where, F_1, F_2, \dots, F_n denote the different classifications of bridge deck damage states, respectively, and $\mu_1, \mu_2, \dots, \mu_n$ denote the affiliation function of the corresponding classification, i.e., the degree of the bridge deck in this damage state, respectively.

3.3 Implementation of Bridge Deck Damage Detection Methods

The main steps in the realization of the bridge deck damage detection method are as follows:

Step 1: Damage inspection of the bridge deck slab to determine its damage status;

Step 2: The bridge deck damage state is fuzzified according to the bridge deck damage state model;

Step 3: Evaluate and analyze the fuzzy post-fuzzy bridge deck damage state using fuzzy comprehensive evaluation method to determine the damage level and damage location of the bridge deck;

Step 4: Classify and determine treatment measures for bridge deck damage class and damage location.

4. Finite Element Modeling and Calculations before Reinforcement of Bridge Deck Plates

The commonly used bridge deck thickening reinforcement method for finite element simulation, bridge deck model selection of a city reinforced concrete bridge deck, according to the original size for the establishment of finite element model, the size of the bridge deck model before reinforcement is shown in Fig. 1.

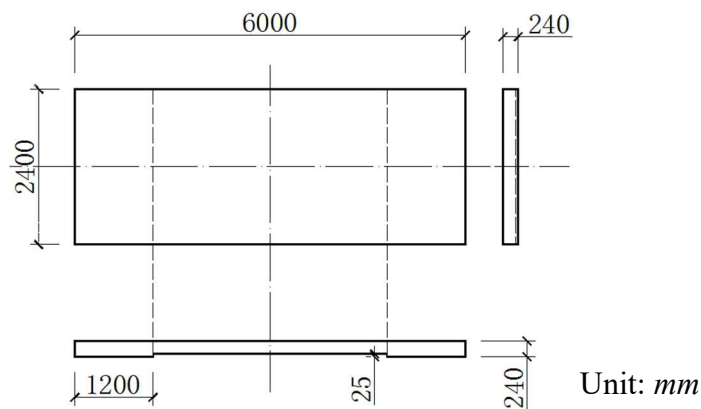


Fig. 1 Dimensions of the bridge deck model

4.1 Finite Element Modeling and Calculation before Reinforcement of Bridge Deck Plates

According to the model dimensions of the bridge deck in Fig. 1, the vehicle load distribution in Fig. 5.4, and the given material properties, the finite element model of the bridge deck is carried out, and the finite element model of the bridge deck before reinforcement is shown in Fig. 2.

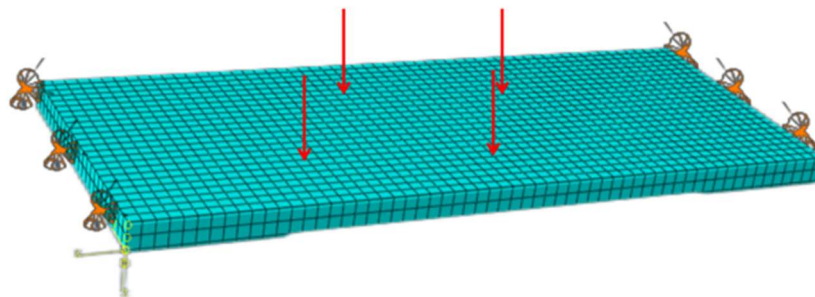
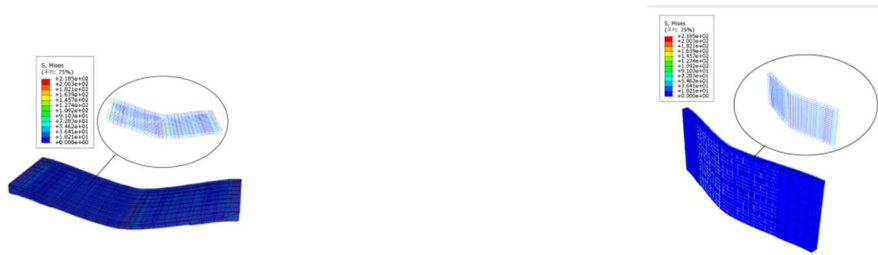


Fig. 2 Model of bridge deck slab before reinforcement

Through finite element simulation, the cloud diagram of principal stress distribution and the cloud diagram of Y-direction displacement distribution of the bridge deck plate before reinforcement were obtained, as shown in Fig. 2.



(a) Cloud map of principal stress distribution on the traveling surface (b) Cloud map of principal stress distribution on the spalled surface

Fig. 3 Cloud diagram of principal stress distribution of bridge deck slab before reinforcement

4.2 Finite Element Modeling and Calculation after Reinforcement of Bridge Deck Plate

The reinforced concrete is selected with strength class C35, and its standard values of compressive and tensile strength are $f_{ck} = 23.4 N/mm^2$, $f_{tk} = 2.20 N/mm^2$, modulus of elasticity $E_c = 3.15 \times 10^4 N/mm^2$, and the rest of the model parameters are the same as those before reinforcement. The modeling of the bridge deck after reinforcement is shown in Fig. 4.



Fig. 4 Model of bridge deck after reinforcement

Through finite element simulation, the cloud diagram of principal stress distribution and the cloud diagram of Y-direction displacement distribution of the bridge deck plate after reinforcement are obtained, as shown in Fig. 5.



(a) Cloud diagram of principal stress distribution on the traveling surface (b) Cloud map of principal stress distribution on the spalled surface

Fig. 5 Cloud diagram of principal stress distribution of bridge deck slab after reinforcement

5. Conclusion

With the development of transportation, bridge maintenance is becoming more and more important, and bridge deck damage detection and analysis has become a crucial part of bridge maintenance work. This paper proposes a fuzzy mathematics-based bridge deck damage detection and analysis method, which uses fuzzy mathematical theory to model and analyze the damage state of bridge decks, with high accuracy and robustness, and can effectively improve the efficiency and safety of bridge

maintenance. In the process of practical application, the method needs further improvement and refinement.

References

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