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Experimental Teaching Reform of Concrete Member Crack Observation and Reinforcement Location

Chengzhu Qiu*

School of Civil Engineering, University of Science and Technology Liaoning, Anshan 114051, Liaoning, China

*Author to whom correspondence should be addressed.

Abstract: In the development framework of engineering colleges, the cultivation of students' practical ability has received unprecedented attention. Based on the actual situation of the experimental teaching of the bridge direction of the road and bridge specialty in our school, the targeted teaching experiment reform was carried out, and the comprehensive experiment of the positioning of the crack observation grade steel bar of the reinforced concrete beam was customized, so that the students were fully trained in the application of professional software, experimental hands-on skills, information data analysis and processing, and bridge detection ability. It broadens students' practical ability and professional vision, and lays a good foundation for future work and employment.

Keywords: Teaching; Numerical; Analysis; Experiment

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1. Introduction

In 2020, the Ministry of Transport issued the Opinions of the Ministry of Transport on Further Improving the Safety and Durability of Highway Bridges, in 2021, the Ministry of Transport formulated the Implementation Plan for the Construction of the Health Monitoring System for Highway Long Bridge Structures. In 2022, the Ministry of Transport promulgated the Technical Specification for the Monitoring of Highway Bridge Structures. Now the country is paying more and more attention to the monitoring, maintenance and reinforcement of existing bridges. In the case of meeting the needs of use, the monitoring, maintenance and reinforcement of bridges have important economic significance and value [1].

At present, concrete beam bridge is widely used in bridge engineering because of its many advantages. Therefore, its quality detection and performance evaluation are very important and need to be solved in bridge engineering at present. Nondestructive testing technology can be used to estimate the structural and mechanical properties of concrete beams simply and quickly, and to locate and measure their internal defects, which plays an important role in the diagnosis, maintenance and repair of bridge structures. Generally speaking, the nondestructive testing of concrete beams includes integrity and strength testing. In recent years, there is no new method or new major breakthrough in the nondestructive testing of concrete beam strength, and the traditional rebound method and ultrasonic method are still the main methods to test concrete strength [2].

The integrity test of concrete beams mainly includes internal defects, such as cracks, cavities, segregation, sediment and the location of prestressed tendons and the distribution of steel bars, the thickness of protective layer and the degree of corrosion.

The crack of bridge concrete component and the location of steel bar are the key items in bridge detection, so it is one of the experimental contents of "Road and Bridge Detection and Reinforcement Technology". The purpose of this experimental project is to enable students to master the necessary practical content of bridge non-destructive testing, improve students' ability of integrating theory with practice, and better engage in professional work in the future.

2. The purpose of this experiment reform

2.1. Optimization of experimental models for concrete crack detection and rebar localization

At present, there is only one concrete beam used in the experiment of concrete crack and steel bar location, which is a scaled model of beam with dense steel bars, so it is not suitable for experimental teaching model, and it cannot meet the needs of group experiments of two professional classes. Therefore, according to the requirements of the experimental purpose, for the crack experiment, five groups of components with different depths and widths of crack width are needed, and for the positioning of steel bars, ten groups of concrete components with different diameters and spacing of steel bars are needed, so as to ensure that the experimental purpose and requirements are achieved, so that students can really master the experimental practice ability [3].

2.2. Numerical simulation and optimization of reinforced concrete beam models

Use the numerical simulation method to establish the model of the beam body, and load and check the relevant indicators to ensure the accuracy of the model. The beam model is optimized by adjusting the reinforcement of the model to achieve the purpose of optimal design, and the students' rational understanding of the economic rationality of the project was trained [4].

2.3. Role of comprehensive experiments in achieving educational objectives

The comprehensive experiment enriches the content of the experiment, reflects the purpose of the experiment, achieves the goal of the experimental course, and lays a good foundation for the follow-up graduation design.

2.4. Exploration of numerical simulation methods in civil engineering education

At present, the numerical simulation test method is seldom used in the experimental teaching of civil engineering courses in China. We put forward the numerical simulation test method and made some attempts and explorations in the relevant courses, which explores the formation of the numerical simulation test system for the college [5].

3. Basic contents of the experimental reform project

In order to meet the objectives and tasks of experimental teaching, this teaching reform experiment includes the following main contents.

(1) For the steel positioning experiment, several groups of components were made, the section of the component was 10–20 cm, the diameter of the steel bar was 10 mm, 14 mm, 16 mm, 20 mm, 24 mm, and the spacing of the steel bar was 5 cm, 10 cm, 15 cm.
(2) For the crack width and depth test, three groups of different rectangular reinforced concrete beams need to be made and placed for about a month, and then loaded in the civil experiment hall. After the loading is damaged, the loading continues until multiple cracks appear, forming cracks with different widths and depths, so as to facilitate the experimental detection and grouping.
(3) A steel bar tester was used to detect that steel bar position, the steel bar diameter, the protective layer and the like of the manufactured component.
(4) A numerical model was established by using bridge finite element software MIDAS, give that size and reinforcement of a student concrete beam, establishing a concrete numerical model by using Midas civil, and applying a load.
(5) Load the rectangular reinforced concrete beam according to the designed function, test its bearing condition, and use the detection equipment to detect its performance such as cracks, deflection, and more. The position and diameter of the steel bar, the thickness of the protective layer of the beam, the crack and deformation at the bottom of the beam are detected by using the concrete steel bar tester and the concrete crack tester.
(6) Loading the numerical model in combination with the actual bearing capacity, comparing the mechanical properties of the actual beam body and the modeled beam body, and evaluating the accuracy of the numerical model.

4. Key problems and innovations to be solved

4.1. Key issues

How to determine the reasonable diameter and spacing of stirrups and stressed bars to reduce and avoid the influence of cross bars, and how to ensure that the model established by MIADS finite element is highly consistent with the actual beam.

4.2. Innovation

The general experiment only has the actual component examination step, this experiment uses the numerical simulation way to verify the entity load concrete beam body the examination result, enhances the student to use the finite element software to carry on the numerical simulation the ability. Targeted components are developed for steel positioning and crack detection, the experimental results are clearer, and the experimental objectives are better achieved.

5. Implementation plan and process of the reform project

(1) Aiming at a steel bar measuring experiment, concrete segments with different positions, different diameters and different sections are made.
(2) Aiming at the crack test, a concrete rectangular reinforced concrete beam is manufactured, and after the construction steps of steel bar binding as shown in **Figure 1**, strain gauge connection, concrete pouring, curing and the like of the concrete beam are completed in a laboratory, the concrete beam is stood for about one month to prepare for the test as shown in **Figure 2**.

(3) The process operation of nondestructive testing of fabricated components by steel bar tester was shown in **Figure 3**, including steel bar positioning, steel bar diameter, protective layer, and more.
(4) The bridge finite element software MIDAS is used to establish the numerical model,the established finite element model is shown in **Figure 4**.
(5) Rectangular reinforced concrete beams were loaded according to the designed function to test their bearing capacity, and their performance (cracks, deflection, etc.) Is tested by testing equipment. Based on the experiment, we can obtain the deflection and crack data of the beam, as shown in **Figure 5**.
(6) Then, the numerical model was loaded, the mechanical properties of the actual beam body were compared and the modeled beam body, and the accuracy of the numerical model was evaluated.

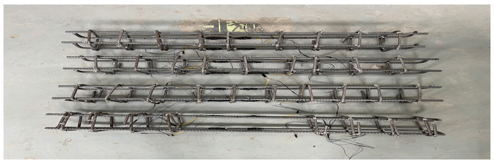

Figure 1. Reinforcement skeleton of beam.

Figure 2. Forming of reinforced concrete beam.

Figure 3. Rebar positioning detector.

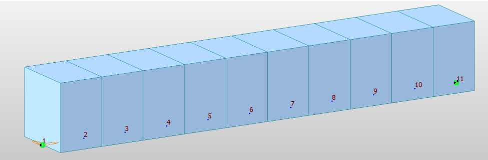

Figure 4. Midas civil finite element model of concrete beam.

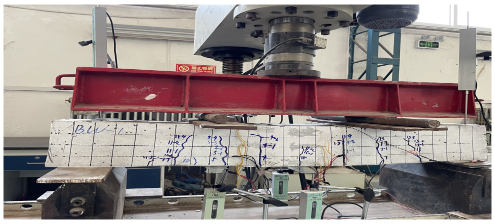

Figure 5. Loading of concrete beam.

6. Analysis of the effect of experimental teaching reform

Through the joint efforts of teachers and students, the one-and-a-half-year experimental teaching reform project has been completed. Through this reform, the scale model and numerical model of concrete beams and single components are established, the bridge non-destructive testing is carried out safely, and the structural optimization design of the numerical model is carried out.

6.1. Establishment of reusable scale models for bridge non-destructive testing education

This reform has solved the problem that students have no components to test in the non-destructive testing of bridges, and the scale model of concrete beams established can continuously provide testing purposes for subsequent students, and has good pertinence.

6.2. Training in modern testing equipment for structural health monitoring

Students have mastered the use of four kinds of experimental equipment in the detection experiment, including the principle of crack observation and the use of crack width gauge, the principle of steel position measurement and the use of concrete steel detector, the sticking technology of strain gauge, the operation method of resistance strain gauge, and the method of using resistance strain gauge to measure the strain value of components. The application capability of the modern detection equipment is improved.

6.3. Developing student competence in independent numerical modeling

The students establish the numerical model independently. The students are interested in the application of information software and encounter many difficulties in the modeling. After the research of the same group and the guidance of the teacher, they finally overcome many difficulties and establish the numerical model of the slab bridge with high precision and good reliability, which lays the foundation for the successful completion of the numerical simulation part.

6.4. Enhancing experimental safety in student centered teaching reform

In the experimental reform, because of the participation of students, the safety of the implementation process has put forward higher requirements, teachers start from safety, check the dangers that may be encountered in the experiment one by one, and put forward targeted safeguards, such as the use of cutting machines to cut steel bars and other operations, using protective masks. It not only ensures the safety, but also reflects the student-oriented experimental teaching concept.

7. Conclusion

In this experimental reform, teachers and students participate in and plan together, and do everything in detail in the experiment, which ensures the success of the experimental reform.

In this experiment, reinforced concrete beams and related single components are made to meet the needs of students in the non-destructive testing of bridges. Before and after loading, the testing equipment and instruments are used to test them. On the one hand, the students' practical ability is improved, on the other hand, the students' application ability of testing knowledge, testing methods and technology is improved.

Use the numerical simulation method to establish the model of the beam body, and load and check the relevant indicators to ensure the accuracy of the model. The beam model is optimized by adjusting the reinforcement of the model to achieve the purpose of optimal design, and the students' rational understanding of the economic rationality of the project is trained.

The comprehensive experiment enriches the content of the experiment, reflects the purpose of the experiment, achieves the goal of the experimental course, and lays a good foundation for the follow-up graduation design.

In the teaching reform project, the method of numerical simulation test is put forward and some attempts and explorations are made in the relevant courses, which explores the formation of the numerical simulation test system in the school.

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Disclosure statement

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