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Teaching Research on the Course of Design of Steel Structures Based on Practical Tests: A Case Study on Design of Columns in China

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Abstract

As one of the most important course in the field of civil engineering, the "Design of Steel Structure" is attracting attentions from college teacher in China. The complex failure modes or buckling modes of steel components result in comprehending deviation of students between theoretical models and engineering practice. This paper proposes a teaching research on the course based on practical tests, and presents a case study on design of steel columns in China. The buckling modes and finial failure modes of the cold-formed steel (CFS) columns were visually shown in the tests, and they were compared to the theoretical presentations in textbooks. Besides, a standard testing-teaching procedure is also recommended for further teaching research for other course closed to the engineering practice.

Keywords: steel structure, teaching research, practical tests, standard testing-teaching procedure

1. Introduction

"Design of Steel Structure" is one of the most important course for the students major in civil engineering. Steel structures have developed rapidly in the field of construction and are widely used in high-rise buildings, super high-rise buildings, and industrial buildings (Xingyou Yao & Yanli Guo, 2019). This is because steel structures have more prominent advantages compared to traditional reinforced concrete structures, such as lighter weight, higher strength, better overall integrity, good seismic performance, and environmental friendliness, among others. The country is vigorously promoting the development of prefabricated steel structure buildings. According to statistics from the Ministry of Housing and Urban-Rural Development, the proportion of prefabricated steel structure buildings in new construction in 2020 was about 30.2%. The industry's development has increased the demand for talents in this field, further increasing the social demand for steel structure professionals.

In the "Design of Steel Structure" course, students mainly learn the characteristics of steel structures, the connection performance, theoretical calculations, and stability verification of compressed and flexural members, laying a foundation for their future work in this field.

The course is closely related to the practice of steel structure engineering, including theoretical calculations and on-site processing. However, currently, most of the college students have limited practical exposure to steel structures and a lack of understanding of tests in China. In order to cultivate students' better understanding of this course and the combination of theory and experiment, the practical experiment on the mechanical performance enhancement of composite columns is introduced to connect with the theoretical knowledge in the textbook and further improve the teaching quality.

2. Research Background

The current teaching status of the "Design of Steel Structure" course is such that almost all universities with civil engineering majors offer this course. However, due to the traditional teaching methods of this course, there are usually the following problems:

2.1 Disconnection Between Theory and Practical Tests

The traditional "Design of Steel Structure" course focuses too much on the imparting of theoretical knowledge, and the engineering experiment examples are explained solely by the teacher, neglecting the cultivation of practical skills. Students acquire theoretical knowledge in the classroom but lack opportunities for practical tests. This makes it difficult for students to apply the learned theoretical knowledge to understanding and mastery in some complex project nodes.

2.2 Lack of Comprehensive Design Ability Training

Traditional courses usually focus on teaching basic concepts and regulations but rarely involve the cultivation of comprehensive design abilities. Design of Steel Structure require students to have the ability to consider and balance design principles, structural performance, and economy. However, these aspects receive less attention in traditional theoretical courses.

2.3 Lack of Connection with Real Engineering Projects

Traditional courses often disconnect from the needs of actual engineering projects. Students learn a lot of theoretical knowledge in the classroom but lack engineering practice. They have a limited understanding of steel structure engineering and struggle to combine this knowledge with actual engineering projects. This hinders students' grasp of the essence of steel structures and may result in difficulties in adapting to practical work and solving engineering problems (Tao Li, 2022; Zhanyuan Gao, Fang Yang, Huidong Zhang, et al., 2022).

3. Teaching Research Method Based on Practical Tests on Steel Structure

The goal of this teaching research is to establish a curriculum system based on the combination of theoretical knowledge and practical engineering tests to improve the teaching effectiveness and students' interest in the "Design of Steel Structure" course.

The specific steps of the methods for implementing the teaching research are listed as follows.

3.1 Introduction of Practical Experiment Teaching

Incorporate practical experiment elements into the course, allowing students to apply the theoretical knowledge they have learned to practical scenarios through actual projects, tests, and simulation exercises. This cultivates their practical application skills.

3.2 Strengthening Comprehensive Design Training

Train students' comprehensive design abilities through case analysis and project practice. Teachers can introduce actual engineering projects and allow students to try to solve practical design problems, thereby enhancing their ability to consider and solve problems comprehensively.

3.3 Enhancing Industry Connections

Collaborate with relevant companies or professionals in the construction industry, inviting them to participate in the course teaching, providing real cases and sharing experiences. This allows students to better understand industry demands and the latest development trends.

4. Practical Experiment Section:

4.1 Differentiation of Test Buckling Modes and Failure Modes

Traditional teaching lacks intuitive explanations of overall buckling, local buckling, and distortion buckling. Based on the experimental results, this research visually displays the differences between different types of buckling to the students. (A-Cross-section, S-Short column, M-Middle column, 90-web height, 1-rib addition, 2-web rib addition, 3-corner rib addition)

4.2 Standard Experimental Process on a Case Study of a CFS Column

4.2.1 Preparation and Design Stage

Study relevant knowledge and analyze research results related to steel materials domestically and internationally. Compare the mechanical properties and prices of various steel manufacturers' materials and conduct material tests for new materials. Determine the parameters and variables of the test specimens. In this study, the influence of basic component properties, thickness, screw spacing, etc., on the load-bearing capacity of composite columns was analyzed. Carry out bending and forming of the specimens on-site to obtain the required cross-sectional shape and other connection and stiffening specimen, design multiple sets of experimental plans, and discuss, optimize, and select the best plan.

4.2.2 Component Fabrication and Test Loading Stage

Complete the assembly of the steel column and learn how to use the laboratory axial pressure testing instrument. After measuring the initial defects of the axial compression specimens, conduct axial compression tests. The steps of the cold-formed steel composite column axial compression test include the following:

- Scheme design and specimen assembly: Carefully handle the electric drill and check its performance before use. Mark out the hole positions and drill perpendicular to the object. Control the drilling speed from slow to normal.

- Measuring the initial defects of the specimens: For composite components, only measure the initial mid-span deflection δ and initial irregularity δ_l. The method for measuring the initial mid-span deflection is as follows: Place the specimen on a flat and sturdy surface and place displacement gauges at both ends and the middle point of the specimen to measure the displacement in the middle of the specimen. For measuring the surface irregularity of the plates, fix the specimen on the measuring platform, place a rigid rod on the selected plate, measure a value using a dial gauge, and then remove the rigid rod and measure another value. The difference between these two values represents the plate's irregularity.

- Installation of strain gauges and displacement gauges: Install strain gauges on the single-limb components of the composite specimen to measure the corresponding longitudinal strain and buckling critical load.

Place horizontal displacement gauges at the upper 1/4, lower 1/4, and mid-section positions of the composite column specimens. Install displacement gauges at the bottom plate to measure the axial deformation of the specimens. Install another displacement gauge at the bottom of the specimens to measure the top horizontal displacement. For short column specimens, only place horizontal displacement gauges at the mid-section position.

- Instrument preparation and preliminary experiment: Place the assembled specimen on a pre-positioned rigid pad or testing machine platform. Perform initial geometric alignment, tighten the bolts, and connect the strain gauges and set up the displacement gauges. Apply a pre-load of 2kN to the specimen with a speed of 1kN/min. Observe the readings of the strain gauges in the middle of the specimen and check the alignment of the specimen. If there is a deviation, adjust the position of the specimen and preload again until the strain meets the requirements. Check all instruments and equipment to ensure normal operation before officially starting the loading.

- Formal loading and recording of test phenomena: Apply the load using displacement control with a speed of 0.5mm/min and a step load of 0.5mm. Hold the load for 2 minutes and allow the computer system to automatically collect data from all measurement points until the load decreases to 85% of the peak load or the specimen visibly fails and is unable to bear the load. Stop loading. Observe and record the test phenomena and corresponding loads during the test.

- Unloading and recording of test data.

4.2.3 Numerical Simulation Data Processing Stage

Conduct numerical simulation research and parameter analysis of stainless steel composite columns. Modify and optimize the existing Abaqus numerical simulation model and complete academic papers based on the experimental and numerical simulation results.

5. Conclusions

It is believed that using the entire process of CFS column tests to assist in teaching the "Design of

Steel Structure" courses will help students understand the theoretical knowledge of steel structures, increase their interest in learning the course, and lay a certain practical foundation, which is the foundation for future career development. To further improve the teaching quality, our future efforts can integrate the advantages of current BIM technology, such as visualization, simulation, and drawing, into classroom teaching, which is expected to achieve good results.

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