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Reforming Civil Engineering Practice Teaching: A Case Study on Material Testing in Civil Engineering

Lingxu Li [1, *], Mingchang Ma [2], Zitong Ma [2], Yifeng Sun [3]

[1] Dianchi College of Yunnan University, Kunming, Yunnan, China
[2] Changchun Institute of Technology, Changchun, Jilin, China
[3] Jilin University, Changchun, Jilin, China

*** Corresponding author:** Lingxu Li

Abstract: Currently, applied universities in China are advancing the reform of training models to foster well-rounded student development in areas of ethics, intellect, physical fitness, aesthetics, and practical skills. These institutions place a strong emphasis on social practice education, continuously enhancing training quality, integrating diverse cultural elements, and cultivating professionals with practical innovation and modern management skills. The civil engineering program specifically aims to develop high-caliber professionals with a solid grounding in contemporary civil engineering theories and techniques. As an essential practical course within the Civil Engineering Materials curriculum, the Civil Engineering Materials Testing course plays a critical role in fulfilling graduation requirements. Given evolving societal, economic, cultural, scientific, and technological needs, this course holds a foundational and central position in the civil engineering talent training system.

Keywords: Applied University; Civil Engineering; Material Test; Teaching Reform; Personnel Training.

1. Introduction

1.1. Culture Orientation

The Civil Engineering Materials Testing course is a foundational practical class that prepares students for entry into the professional field. Through hands-on experiments, students learn to perform performance testing and operational procedures for various commonly used materials, building essential skills for engineering design and construction. This foundation equips them with the competencies in material testing and quality control required in real-world engineering. Ye Huan et al. [1] developed an experimental project centered on recycled concrete within the "dual carbon" policy framework. Expanding on traditional experiments, this project incorporates optional variables, enriched content, and an independent design component, enhancing student engagement and enthusiasm for learning.

1.2. Improve Engineering Literacy

The course enables students to understand the physical, mechanical, and chemical properties of civil engineering materials, enhancing their engineering knowledge by teaching them material properties and application standards. In practice, a strong grasp of material properties directly impacts the design, construction, and durability of engineering structures. Civil Engineering Materials Testing also fosters students' awareness of selecting and applying materials effectively, preparing them for informed and scientific decision-making in their future work.

1.3. Cultivating Innovation and Research Quality

The Civil Engineering Materials Testing course tightly integrates fundamental theoretical knowledge with engineering applications, enabling students to connect theories in mechanics, structural science, and materials science with hands-on experimental data. This foundation prepares students to tackle complex engineering problems in the future, reinforcing the practical application of knowledge in professional settings. In their work, Xing Guangyan et al. [4] examined the current teaching practices of the Civil Engineering Materials Testing course with the goal of nurturing high-quality engineering and technical talent. Using the comprehensive testing of recycled aggregate pervious concrete as a case study, they discussed innovative teaching approaches for this course.

The course goes beyond material knowledge, aiming also to foster students' innovative thinking and research skills. Through experimental design and performance analysis, students explore the development of new materials or modifications to existing ones to meet the demands of increasingly complex engineering environments. This process nurtures research-oriented thinking, laying a foundation for future exploration in fields like material modification and sustainable building materials. Feng Leilei [5] examined the current teaching approach of Civil Engineering Materials Testing in applied undergraduate programs and proposed paths for innovative teaching improvements.

1.4. Cultivating Safety and Standard Awareness

The Civil Engineering Materials Testing course enforces strict guidelines for operation procedures and experiment management, instilling students with a strong sense of safety awareness and professional standards. This rigorous focus on safety education and standardized practices aligns with the engineering industry's requirements for safe production, ensuring that students develop fundamental professional discipline and safety protocol awareness for their future careers.

1.5. Improvement of Comprehensive Ability

The Civil Engineering Materials Testing course enhances students' overall abilities in data analysis, report writing, logical reasoning, and more. Through the process of

translating experimental results into meaningful conclusions and presenting them rigorously, students develop key communication and reporting skills that are highly valuable in the engineering industry. Thus, the course serves not only as a technical learning process but also as a crucial component in cultivating engineering literacy, practical skills, and innovative thinking. The primary goal of the course is to nurture engineering professionals with strong hands-on abilities, a mindset of innovation, and proficiency in standardized operations, ensuring that students acquire the essential professional skills and comprehensive competencies required in the civil engineering field.

2. Course Features

The Civil Engineering Materials Testing course has distinct teaching characteristics and holds a vital position within the civil engineering discipline. It serves as a practical component of the civil engineering materials curriculum, designed to help students master the basic properties, testing methods, and application characteristics of materials. Some of the key features of the course include:

2.1. Combination of Theory and Practice

The Civil Engineering Materials Testing course emphasizes a strong integration of theory and practice. It not only covers the theoretical aspects of materials' mechanical, physical, and chemical properties but also includes hands-on laboratory work. Through practical experiments, students gain a deeper understanding of the actual performance and application of materials such as cement, reinforcement, concrete, and soil in real-world engineering scenarios.

2.2. Training of Experimental Skills

This course emphasizes the development of students' practical skills in material testing, including sample preparation, instrument calibration, and data collection. Through hands-on experience, students learn the test procedures, acquire the ability to conduct standard material tests, and develop skills in identifying and analyzing errors in experimental data.

2.3. Data Analysis and Report Writing

The course typically requires students to analyze data and interpret results after completing experiments, followed by writing a standardized experiment report. This process not only enhances students' data processing and analysis skills but also fosters their logical thinking and written communication abilities. These competencies enable students to scientifically analyze material properties and effectively present their findings in future engineering projects.

2.4. Pay Attention to the Application of Material Properties

Civil Engineering Materials Testing courses emphasize the application of experimental results to real-world engineering scenarios. For example, students analyze the suitability of materials for bridges, buildings, and other structures by assessing performance indicators such as compressive and tensile strength. This approach helps students understand the significance of material properties in meeting the practical needs of engineering projects.

2.5. Innovation and Scientific Research Literacy

Some courses also incorporate design and innovative experimental components, allowing students to explore the impact of different material proportions or modification processes on material properties. Additionally, students may investigate the performance of new materials, fostering their innovative thinking and interest in scientific research. This approach provides a solid foundation for future research and development in the field.

3. Teaching Methods

In the Civil Engineering Materials Testing course, the selection of teaching methods should facilitate a deep understanding of material characteristics and the experimental process, while enhancing practical operation skills. The following teaching methods are typically employed:

3.1. Combination of Lecturing and Case Teaching

By teaching fundamental theoretical knowledge, such as the physical, chemical, and mechanical properties of materials, alongside practical engineering cases, students gain a clear understanding of material performance requirements in various applications. For instance, when teaching concrete's compressive strength, the importance and testing process are demonstrated through real-world building construction cases, helping students better grasp the link between theory and practice [3].

3.2. Experimental Demonstration Method

In experimental teaching, instructors begin by demonstrating the experimental procedures, such as operating instruments, preparing samples, and following experimental steps. This allows students to visually grasp the correct methods of operation. The demonstration approach is particularly effective for complex instruments, enabling students to learn through observation and minimizing the likelihood of errors during the experiment.

3.3. Group Cooperative Learning

Before the course begins, students are organized into experimental groups of 4 to 8 members, tasked with collaboratively designing the experiment, performing the operations, and analyzing the data. This approach not only fosters teamwork but also encourages the sharing of experiences and mutual learning, thereby deepening students' understanding of the experimental content.

3.4. Inquiry Teaching

The inquiry-based teaching method is employed to encourage students to actively engage in critical thinking and problem-solving. For instance, during material modification experiments, students are encouraged to design their own formulas or processes and investigate how different parameters affect material properties. This approach helps stimulate their innovative mindset and enhances their ability to think independently.

3.5. Scenario Simulation and Role Play

Real-world engineering scenarios are created for students, such as simulating an actual construction material inspection

site. This allows students to experience the entire process, from material testing and result analysis to report writing, in the role of "engineering inspection personnel." This approach helps students understand the professional demands of the field and enhances their practical awareness and professional competence.

3.6. Problem-driven Teaching

By presenting material property challenges from real-world engineering scenarios, students are encouraged to conduct experiments based on these issues. For example, posing questions like "How can we improve the crack resistance of concrete?" motivates students to find solutions through hands-on experimentation. This approach clarifies learning objectives and stimulates students' interest and motivation in their studies.

3.7. Information-based Teaching

In theory-based teaching, multimedia courseware, virtual experiment platforms, simulation software, and other digital tools are utilized to enhance learning. For instance, virtual simulation experiments allow students to experience the material testing process in a digital environment, helping them understand the experimental procedure in advance. Additionally, students can analyze data using software, which strengthens their ability to process experimental results.

3.8. Experimental Report Writing and Comment

After completing the experiment, students are required to write a detailed report, including the purpose, steps, data analysis, and conclusions. Teachers provide feedback on the report, addressing any issues and helping students improve their data analysis and writing skills. This process also fosters a rigorous scientific approach and enhances professional reporting abilities.

These teaching methods not only improve students' experimental skills but also cultivate their engineering literacy and innovative thinking, equipping them with the practical abilities needed for material property testing and application in civil engineering.

3.9. Pay Attention to the New Progress of the Discipline

Teaching materials form the foundation of the curriculum, but their updates take time, while the field of civil engineering materials is advancing rapidly. Therefore, it is essential to stay informed about the latest developments in civil engineering materials research and engineering applications, incorporating these advancements into teaching as they emerge. Additionally, with the introduction of new materials and technologies, relevant quality standards and design and construction regulations will also evolve. This updated content should be integrated into the teaching process to help students stay current with industry developments, expand their professional horizons, foster innovative thinking, encourage a spirit of exploration, and enhance their engineering awareness and quality.

4. Teaching Resources

4.1. Offline Teaching Resources

In offline teaching of the civil engineering materials testing course, having rich and comprehensive teaching resources is crucial for enhancing the teaching effect and improving students' learning experience. The key offline teaching resources include:

4.1.1. Material Testing Laboratory

(1) Equipment and Instruments: The laboratory is equipped with various civil material testing instruments, such as concrete pressure testing machines, universal material testing machines, tensile testing machines, soil compression testing machines, and a new asphalt ductility tester introduced this year. These instruments ensure that students can conduct comprehensive material performance testing.

(2) Experimental Benches and Safety Protection Facilities: The experimental benches are designed to meet the spatial requirements for equipment operation. They are also equipped with safety protection features, including protective gloves, goggles, safety signs, etc., to ensure students' safety during experiments. Lu Tao [2] discusses the effective management of civil engineering materials testing, highlighting management strategies and offering recommendations based on actual case analyses.

4.1.2. Experimental Manual and Operating Guide

(1) Detailed Experimental Manual: This manual provides comprehensive instructions on the experimental principles, equipment usage, experimental steps, data processing methods, and safety precautions. It serves as a handy reference for students during their experiments.

(2) Simplified Operation Guide: A simple operation guide or safety instructions are provided next to the equipment, helping students quickly understand how to use the instruments correctly and the safety precautions to follow.

4.1.3. Course Notes and Textbooks

(1) Systematic Course Notes: These notes cover the basic theories and performance testing methods of common civil engineering materials, including cement, reinforcement, concrete, asphalt, and soil. The notes assist students in preparing for lessons and reviewing content after class.

(2) Experimental Materials: Selected experimental materials are aligned with the course syllabus, ensuring that content is rigorous and related to real engineering practices, which helps students systematically learn the characteristics and operation methods of materials.

4.1.4. Teaching Aids and Models

(1) Material Models: Before starting experiments, the teaching team first tests the purchased materials and equipment. Physical models of prepared samples are used to show the structure, composition, and construction applications of different materials, helping students better understand the physical properties of materials and their engineering applications.

(2) Sample Display: Samples of commonly used building materials, such as cement, sand, steel bars, and bricks, are displayed to allow students to visually comprehend the composition and characteristics of these materials.

4.1.5. Project Case Base

(1) Practical Engineering Cases: By showcasing real-world engineering cases, such as material selection and material testing reports, students can appreciate the practical value of material testing in engineering and enhance their awareness of its real-world applications.

(2) Problem Analysis and Case Discussion: Students engage in discussions about material-related issues in engineering projects, fostering critical thinking and problem-solving abilities related to material properties.

4.2. Online Teaching Resources

In the online teaching of the civil engineering materials testing course, rich online resources play a crucial role in helping students learn theoretical knowledge, understand the experimental process, and conduct data analysis. Luo Ling et al. [6] discuss the concept of blended teaching, focusing on the integration of online platforms, offline courses, and curriculum objectives. This approach optimizes both the teaching and learning processes, aiming to improve the effectiveness of civil engineering material courses. The following online resources are available for this course:

(1) Teaching Videos and Experimental Demonstrations

Experimental Operation Teaching Videos: Professional experimental operation videos are either shot or obtained to showcase each step of the civil material testing process. These videos help students intuitively learn the experimental methods and the data processing involved in material testing [6].

MOOCs and Open Courses: Students are encouraged to watch relevant online courses related to civil engineering materials. Platforms such as Coursera, EdX, Xuetang Online, and others offer courses on material properties, testing standards, and related content.

(2) Interactive Classroom and Online Teaching Platform

Online Classroom Systems: Tools like WeChat, Tencent Conference, and other online platforms are used for real-time teaching and interaction. Teachers can share presentations (PPT), videos, and other resources while answering student questions in real time, or explaining experimental reports online.

(3) Digital Teaching Materials and Experimental Instructions

Electronic Teaching Materials and PDF Experimental Instructions: These materials provide detailed instructions on material testing, covering experimental procedures, equipment usage, data processing methods, and more. They are convenient for students to preview before class and review afterward.

Standards and Specifications Online Resources: Access to national and industry standards (such as GB, ASTM, etc.) for material testing is provided through an online resource library. This helps students understand the standardized processes and technical specifications involved in material testing.

Online resources offer comprehensive support for the online teaching of civil engineering materials testing courses, from experiment preview and operation guidance to data analysis and assignment submission. This ensures that students can systematically and deeply acquire experimental skills and material knowledge in a remote environment. Additionally, the curriculum integrates ideological and political education goals through the use of an online resource learning platform, aligning with the broader educational objectives of the course.

5. Summary

After the teacher improved the teaching methods and course materials—mainly by integrating visual basic models, videos, and animations—students' interest in the course increased significantly. The majority of students proactively utilized online resources to preview lessons, kept pace with the teacher’s ideas during class, and instances of tardiness and absenteeism were notably reduced. The civil engineering materials testing course has achieved impressive teaching outcomes, enhancing students' theoretical knowledge, experimental skills, innovative thinking, teamwork, and professional qualities. Through this course, students not only develop a strong foundation in material testing but also gain the comprehensive skills and vocational capabilities needed to address practical engineering challenges, providing a solid base for their future careers in civil engineering.

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