Empowering Teaching Reform of the Graduate Course "Cement and Cement Concrete" Strategy Exploration

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Abstract: *Graduate education is the main pathway for cultivating high-level, high-quality, and innovative talents, while course teaching is a necessary link to ensure the quality of graduate cultivation. Taking the graduate course "Cement and Cement Concrete" at the University of Science and Technology Liaoning as an example, this paper elaborates on the empowering teaching reform strategies for graduate professional courses in the field of civil engineering from three aspects: course teaching design, course teaching content and resource construction, and course teaching method reform, so as to provide some reference for the teaching practice of other courses.*

Keywords: *Cement and Cement Concrete; teaching reform; empowering; graduate education*

1. Introduction

With the widespread application of new-generation digital technologies such as artificial intelligence, big data, and cloud computing, society is accelerating towards a new era of intelligence and digitalization[1-3]. The cement and cement concrete industry is also undergoing an industrial transformation from traditional models to intelligent models, and the education sector is consequently experiencing profound changes[4-6]. The traditional "Cement and Cement Concrete" course has shortcomings, such as knowledge updates lagging behind technological iterations and course teaching being limited to textbook content, which urgently need reform. Empowering the teaching of the graduate course "Cement and Cement Concrete" with new-era technologies can effectively improve teaching efficiency and students' practical abilities, promote the intelligent and theoretical development of the discipline and the industry, and thus cultivate interdisciplinary talents in the cement and cement concrete industry who possess both innovative thinking and a sense of responsibility.

In 2025, the University of Science and Technology Liaoning actively promoted the reform of the "1+3+2" education system and strived to build a high-level course system that fits the university's disciplinary positioning and development goals. As the cultivating unit, the School of Civil Engineering continued to set "Cement and Cement Concrete" as a core course in the direction of engineering materials when revising the 2025 version of the professional master's degree training program for civil engineering. The course syllabus is written according to the OBE concept, the teaching method highlights the "student-centered" teaching chain, and various teaching resources have initially possessed the basic conditions for the construction of graduate premium courses.

In the training system for professional master's degree graduate students in the field of civil engineering under the category of civil and hydraulic engineering at the University of Science and Technology Liaoning, the "Cement and Cement Concrete" course is a foundational degree course for graduate students established on the basis of the undergraduate course "Civil Engineering Materials". This course takes "material-structure-performance" as its main thread, organically connects multidisciplinary knowledge such as construction materials, structural mechanics, and environmental engineering, and occupies a core position in the engineering discipline system. It runs through the basic theories of materials science, engineering application practices, and interdisciplinary technology integration, and serves the dual pillar role of both theoretical foundation and practical application.

2. Course Teaching Design

2.1 Adhering to the University's Educational Orientation

The teaching of the "Cement and Cement Concrete" course adheres to the university's educational orientation, upholds the teaching philosophy of "high level, high standard", actively learns from and absorbs the essence of advanced graduate teaching from first-class universities at home and abroad, deeply grasps the actual demands of economic and social development and industrial transformation and upgrading for talents, optimizes the structure of course teaching content based on the connotation of the "1+3+2" education system reform, adds cross-integration cases to the course, and insists on the featured teaching of cross-integration.

2.2 Upholding the Talent Cultivation Objectives

The teaching of the "Cement and Cement Concrete" course upholds the talent cultivation objectives, and the specific requirements for graduate students are as follows: a. They shall abide by laws and regulations, possess a high sense of social responsibility to serve the country and the people, and demonstrate good professional ethics, entrepreneurial spirit, team collaboration spirit, as well as a scientific, rigorous, realistic, and pragmatic learning attitude and work style. They shall be honest and trustworthy, and actively serve China's economic construction and social development. b. They shall master solid fundamental theories and systematic professional knowledge in the field of cement and cement concrete. They shall be familiar with scientific research methods in this field, relevant national policies, regulations, and standards, as well as the frontiers and trends of scientific and technological development such as artificial intelligence in this field. c. They shall master modern technical methods such as analysis, research, and optimization for solving practical engineering problems, as well as advanced technical means such as artificial intelligence. They shall possess innovative awareness and craftsman spirit, and be able to use advanced means and technologies to solve complex engineering problems. d. They shall be able to read foreign literature in the field of cement and cement concrete relatively proficiently and possess a good international perspective.

2.3 Course Construction Serving the Student Population

Approximately 40% of the graduate students in the field of civil engineering at the university choose the engineering materials direction each year to pursue their theoretical knowledge learning, scientific research, and thesis writing. In addition, graduate students in the structural direction mainly conduct scientific research and thesis writing on reinforced concrete structures and composite structures, and their fundamental theories involve the basic knowledge and practical orientation of cement and cement concrete. From the perspective of the student population in the field of civil engineering, about 80% of the students involve the knowledge reserve of cement and cement concrete. Thus, the "Cement and Cement Concrete" course holds an important position in serving the student population in graduate cultivation.

2.4 Positioning of the Course in the Graduate Training Program

In the professional master's degree training directions in the field of civil engineering at the University of Science and Technology Liaoning, three research directions are established: structural engineering, geotechnical engineering, and engineering materials. "Cement and Cement Concrete" is a degree-specific professional course for the engineering materials direction. Cement is a fundamental research direction in the field of materials science and engineering, while cement concrete is an applied research direction at the intersection of materials science, civil engineering, and other disciplines. The two present a "fundamental-applied" progressive positioning in graduate cultivation. Therefore, "Cement and Cement Concrete" is primarily positioned as a core course in the graduate training program.

2.5 Course Objectives of "Cement and Cement Concrete"

Knowledge Objectives: a. Students shall systematically master the core fundamental theories of cement. b. They shall fully understand the composition-structure-performance relationship of cement concrete. c. They shall be familiar with the cutting-edge knowledge of special cements and functional concretes. d. They shall understand the industry standards, engineering specifications, and sustainable

development trends in the field of cement-based materials.

Ability Objectives: a. Students shall possess the ability for theoretical analysis and experimental design. b. They shall have the ability to solve engineering problems. c. They shall possess the ability for literature retrieval and frontier exploration. d. They shall enhance their academic expression and team collaboration skills.

Ideological and Political Objectives: a. Students shall establish the concept of independent learning and lifelong learning. b. They shall establish the concept of sustainable development. c. They shall establish confidence in the path and confidence in culture. d. They shall establish critical thinking skills, cherish patriotic sentiments, and dare to take responsibility.

3. Course Teaching Content and Resource Construction

3.1 Sequence of Knowledge Modules and Corresponding Class Hours

The "Cement and Cement Concrete" course is set as 2 credits with 32 theoretical class hours and ten knowledge modules. Table 1 presents the main teaching content and the allocation of class hours.

Table 1 Knowledge Modules of "Cement and Cement Concrete" and Their Corresponding Class Hours

Knowledge Modules	Main Teaching Content	Class Hour Allocation
Module 1: Basic Knowledge	The definition and classification of cement, the definition and classification of concrete, the development of concrete, and the research content of concrete materials science.	2
Module 2: Concrete Raw Materials	The classification of cement, the components, strength grades, and technical requirements of ordinary Portland cement, the main mineral composition of cement, the classification and technical requirements of aggregates, the technical requirements of water for concrete, and common mineral admixtures.	4
Module 3: Concrete Admixtures	The development overview of chemical admixtures, the basic principles of concrete admixtures, and new varieties and technologies of admixtures at home and abroad.	4
Module 4: Properties of Fresh Concrete	The rheology of fresh concrete, the workability of fresh concrete, the adaptability between cement and admixtures, the main factors affecting the workability of concrete, and segregation and bleeding.	2
Module 5: Structure of Hardened Concrete	The composition and structure of hardened cement paste, the interface of hardened concrete, and the discussions on the structure of hardened concrete by domestic scholars.	2
Module 6: Physical and Mechanical Properties of Concrete	The physical properties of concrete, the strength of concrete, the deformation properties of concrete, and the microscopic failure process of concrete.	2
Module 7: Durability of Concrete	The frost resistance of concrete, the damage to concrete caused by environmental chemical erosion, the alkali-aggregate reaction, the corrosion of steel bars in concrete, the failure law of concrete under the synergistic effect of multiple factors, and the methods for classifying and identifying concrete diseases.	4
Module 8: Concrete Mix Design	The mix design methods for ordinary concrete, high-performance concrete, lightweight aggregate concrete, and other types of concrete, as well as new concepts and methods for mix design.	4
Module 9: Building Mortar	The constituent materials of mortar, the mix design of mortar, dry-mixed mortar, and new technologies for mortar.	2
Module 10: Fracture Mechanics Analysis of Concrete	The failure and fracture mechanisms of concrete, damage mechanics, and its application in concrete.	6

3.2 Key Points, Difficulties, and Solutions of the Course

The key points and difficulties of the "Cement and Cement Concrete" course are relatively extensive. To improve the teaching quality, the course mainly addresses them from five aspects, as detailed in Table 2.

Table 2 Key Points, Difficulties, and Solutions of the "Cement and Cement Concrete" Course

Knowledge Module	Key Points and Difficulties of the Course	Solutions
Module 1: Basic Knowledge.	Key points: The definitions, classifications, and core application scenarios of cement and cement concrete should be clarified, and the course knowledge framework should be established. The functional synergy among the constituent materials of cement and concrete must be mastered. The engineering value and industry development trends (low-carbon, high-performance, intelligent) of this discipline should be understood. Difficulties: Abstract concepts need to be concretized. The integration of related knowledge poses a challenge. The connection between cutting-edge industry developments and fundamental theories is difficult to achieve.	1. The course improves the teacher's knowledge reserve by reading new textbooks from the past three years, key journal papers, and classic works, thereby organizing new knowledge and new technologies and enhancing the depth of theoretical understanding.
Module 2: Concrete Raw Materials.	Key points: The selection of cement grades, the types of sand and stone aggregates, aggregate gradation and mud content control, as well as the balance between strength and workability should be mastered. Difficulties: The fluctuation of material properties and the balance control of performance are challenging. New varieties of raw materials from domestic and international sources present difficulties.	2. The course concretizes teaching by improving multimedia courseware, empowering with AI, and integrating pictures, animations, engineering case videos, and virtual simulations, thereby expanding the breadth and depth of teaching.
Module 3: Concrete Admixtures.	Key points: The mechanisms of concrete admixtures, the methods for balancing concrete performance and cost by adjusting admixtures, as well as the test standards and evaluation methods should be mastered. Difficulties: The adaptability between admixtures and cement is difficult to manage. The contradiction between dosage and cost control poses a challenge. New varieties and technologies of admixtures from domestic and international sources present difficulties.	3. The course organizes logic by building the course on the Chaoxing platform, enriching online teaching resources, using mind maps to construct the "material composition-structure-performance-application" correlation chain, creating a full-course knowledge graph, and strengthening the integration of upstream and downstream knowledge within the course.
Module 4: Properties of Fresh Concrete.	Key points: The basic models of rheology, the workability of fresh concrete, and the adaptability between cement and admixtures should be mastered. Difficulties: The basic models of rheology are difficult to understand.	
Module 5: Structure of Hardened Concrete.	Key points: The composition and structure of hardened cement paste, as well as the interface of hardened concrete, should be mastered. Difficulties: The interface of hardened concrete is difficult to comprehend.	
Module 6: Physical and Mechanical Properties of Concrete.	Key points: The strength of concrete and the deformation properties of concrete should be mastered. Difficulties: The microscopic failure process of concrete is difficult to analyze.	4. The course introduces cutting-edge developments by bringing in hot industry cases, national development strategies, and cutting-edge
Module 7: Durability of Concrete.	Key points: The failure law of concrete under the synergistic effect of multiple factors should be mastered. Difficulties: The methods for classifying and identifying concrete diseases are difficult to apply.	

Module 8: Concrete Mix Design.	Key points: The mix design methods for high-performance concrete, lightweight aggregate concrete, and other types of concrete should be mastered. Difficulties: The new concepts and methods for mix design are difficult to grasp.
Module 9: Building Mortar.	Key points: The mix design of mortar should be mastered. Difficulties: Dry-mixed mortar is difficult to formulate.
Module 10: Fracture Mechanics Analysis of Concrete.	Key points: The failure and fracture mechanisms of concrete, as well as the damage mechanics method, should be mastered. Difficulties: The fracture mechanisms of concrete and the damage mechanics method are difficult to understand.

3.3. Teaching Resource Construction

a. Lesson plan design: The teaching team eliminates outdated chapters, broadens new knowledge and new technologies, carefully reads new textbooks from the past three years, key journal papers, and classic works, thereby organizing new knowledge and new technologies and enhancing the depth of theoretical understanding.

b. Multimedia resource construction: The course empowers with AI and integrates pictures, animations, engineering case videos, and virtual simulations to enhance the effectiveness of theoretical teaching.

c. Chaoxing course construction: The course enriches online teaching resources, uses mind maps to construct the "material composition-structure-performance-application" correlation chain, creates a full-course knowledge graph, and strengthens the integration of upstream and downstream knowledge within the course.

d. Integration of cutting-edge technology: The course introduces hot industry cases, national development strategies, and cutting-edge international conferences and academic reports, and focuses on research hotspots.

e. School-enterprise collaborative course construction: Enterprise experts participate in course construction, and the course invites them to share practical engineering problems and their solutions, as well as new technologies and new concepts from enterprises.

4. Reform of Course Teaching Methods

4.1 Various Teaching Methods Used in the Teaching Process

a. The case analysis method: This method systematically teaches the fundamental theories of high-performance concrete composition design, microstructure evolution, and performance relationships by analyzing practical engineering cases (such as aqueducts and reservoir corrosion protection). It combines theoretical knowledge with engineering practice to help students deepen their understanding of complex problems and stimulate their innovative awareness.

b. The blended teaching method: This method combines online resources (such as multimedia courseware, videos, and virtual simulations) with offline classroom instruction to stimulate graduate students' interest in autonomous learning, promote knowledge internalization, and adapt to the demand for interdisciplinary talents in the context of emerging engineering education.

c. The problem-oriented teaching method: This method uses engineering problems (such as those in the Lhasa plateau region) as drivers to guide graduate students to actively explore solutions and cultivate their critical thinking and innovative abilities.

d. The thematic seminar and flipped classroom method: This method focuses on cutting-edge topics such as "special high-performance concrete, crack control, and health monitoring". It requires students to search literature, prepare PPT presentations, and defend their findings, while the teacher provides comments, thereby achieving a transition from "knowledge reception" to "knowledge creation".

e. The project-based learning and interdisciplinary integration method: This method uses practical

research projects (such as low-heat cement and green high-performance concrete) as vehicles, integrates multidisciplinary knowledge including materials, structures, and the environment, and cultivates graduate students' ability to independently undertake research tasks and their teamwork skills.

4.2 Implementation Process

a. The case analysis method uses the diseases of the Beijing Xizhimen Bridge and the Beijing Sanyuan Bridge as teaching cases for concrete durability. It uses the Beijing Daxing International Airport, the Shanghai Tower, and the high-speed railway in China as teaching cases for high-performance concrete. The new high-performance concrete used in the Hong Kong-Zhuhai-Macao Bridge serves as a teaching case for concrete admixtures, the physical and mechanical properties of concrete, and the durability of concrete. This method helps students deepen their understanding of complex problems through teaching cases.

b. The blended teaching method uses the Chaoxing platform to construct the course, enriches online teaching resources, uses mind maps to build the "material composition-structure-performance-application" correlation chain, creates a full-course knowledge graph, and strengthens the integration of upstream and downstream knowledge within the course.

c. The problem-oriented teaching method, regarding the structure of hardened concrete, starts with a question from a pack of A4 paper: why does the whole pack resist compression while a single sheet tears easily? This question guides students to think about the interface characteristics of the hardened concrete structure. In combination with hot topics such as green building materials and low-carbon cement, this method raises open-ended questions like "How can industrial waste residues be used to replace traditional cement raw materials?" to stimulate research interest. It also raises the question "How can the carbon footprint of concrete be reduced?" and encourages multiple solutions, thereby stimulating innovative thinking.

d. The thematic seminar and flipped classroom method organizes students to carry out thematic seminars and flipped classrooms around cutting-edge topics such as "special concrete", thereby achieving the transition from "knowledge reception" to "knowledge creation".

e. The project-based learning and interdisciplinary integration method carries out project-based learning around provincial and municipal research projects and horizontal projects of the university's School of Civil Engineering, thereby cultivating graduate students' ability to independently undertake research tasks and their teamwork skills. This method integrates national energy conservation and emission reduction policies, the sustainable development strategy, and the concept of green development into classroom teaching, achieving interdisciplinary integration.

5. Conclusion

The construction of the graduate course "Cement and Cement Concrete" at the University of Science and Technology Liaoning adheres to the teaching philosophy of "high level, high standard", emphasizes interdisciplinary integration, optimizes the structure of course teaching content based on the connotation of the "1+3+2" education system reform, continuously carries out teaching resource construction, and can lay a solid foundation for graduate students to engage in research on cement-based materials.

This course has completed the ideological and political education demonstration course construction project, has been recognized by the university's experts, and has won the second prize of the fifth university graduate education reform research and construction achievement award. Currently, no other domestic universities have reported on the construction of university-level ideological and political demonstration for this course.

In the future, the university teaching team will continuously improve and promote the "Cement and Cement Concrete" course, pay attention to industry development trends and academic frontiers, update the course content in a timely manner, improve the teaching materials, and maintain the course's advancement and adaptability. The empowering teaching reform strategy of this course can serve as a reference for other universities.

Fund Projects

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