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

Shuai Tian*

School of Civil Engineering, University of Science and Technology Liaoning, Anshan, 114051, China
**Corresponding author: tian_shuai129@126.com*

Abstract: *Graduate education is the main way to cultivate high-end, high-quality and innovative talents, and course teaching serves as an indispensable link in this process to guarantee the quality of graduate education. The graduate course "Cement and Cement Concrete" at the University of Science and Technology Liaoning is a typical case of the good teaching reform strategy for graduate professional courses in civil engineering presented in this paper, and it consists of three parts: course teaching design, course teaching content and resource construction, and course teaching method reform; this paper hopes to offer some references for the teaching practice of other courses.*

Keywords: *Cement and Cement Concrete; Teaching Reform; Empowerment; Graduate Education*

1. Introduction

With the spread of new-generation digital technologies such as artificial intelligence, big data and cloud computing, society is changing rapidly and entering an era of intelligence and digitalisation [1-3]. The cement and cement concrete industry is also moving from the old model to a smart one, and as a result, the education sector is undergoing considerable changes [4-6]. The traditional "Cement and Cement Concrete" course has deficiencies; that is, it has not kept up with changes in technology, and the content of teaching is limited to textbooks. Strengthening the teaching of the graduate course "Cement and Cement Concrete" with new-era technologies can improve teaching efficiency and students' practical ability, promote the intelligent and theoretical development of the discipline and the industry, and cultivate interdisciplinary talents in the cement and cement concrete industry who have both innovative thinking and a sense of social responsibility.

In 2025, the University of Science and Technology Liaoning actively promoted the reform of the "1+3+2" education system and worked to build a high-quality course system in line with the university's disciplinary position and development goals. As the cultivating unit, the School of Civil Engineering has continued to list "Cement and Cement Concrete" as one of the core courses in the direction of engineering materials in the revision of the 2025 edition of the professional master's degree training program for civil engineering. In accordance with the OBE concept, the syllabus has been developed; various teaching methods will focus on the "student-centered" teaching chain, and some teaching materials have met the basic requirements for constructing graduate premium courses.

In the training system for professional master's degree graduate students in 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 fundamental degree course for graduate students that is based on the undergraduate course "Civil Engineering Materials". The main theme of this course is "Material-Structure-Performance", and it integrates various fields of knowledge, such as building materials, structural mechanics and environmental engineering, within the system of engineering disciplines. The basic theories of materials science, engineering application practices and interdisciplinary technology integration are covered; that is to say, there is a theoretical foundation and also practical application.

2. Course Teaching Design

2.1 Adherence to the University's Educational Direction

In line with the educational direction of the university and the teaching concept of "high level, high standard", we will actively learn from and absorb the essence of advanced graduate teaching at top-tier universities in China and abroad, fully grasp the actual demands of economic and social development and industrial transformation and upgrading for talents, optimize the structure of course teaching content according to the connotation of the "1+3+2" education system reform, add cross-integration cases to the course, and maintain the featured teaching mode of cross-integration.

2.2 Upholding the Talent Cultivation Goals

The teaching of the "Cement and Cement Concrete" course should achieve the goal of cultivating talent, and the specific requirements for graduate students are as follows: They should know the laws and regulations, have a strong sense of social responsibility for serving the country and the people, possess good professional ethics and an entrepreneurial spirit, be able to work well in a team, and have a scientific, rigorous, realistic and practical attitude towards learning and work. They should be honest and trustworthy, and actively participate in the development of China's economy and society. They need to learn the basic theories and organised professional knowledge of the field of cement and concrete. They need to be well-versed in the scientific research method in this field, relevant national policies, regulations and standards, as well as the frontier and trends of scientific and technological development in this area, such as artificial intelligence in this field. They need to learn how to use the new technology for analysis, research and optimisation to solve practical engineering problems, and also be able to use advanced tools such as artificial intelligence. They should have an innovative spirit and a sense of craftsmanship, and be able to use advanced means and technology to solve difficult engineering problems. They should be able to read foreign literature in the field of cement and concrete reasonably well and have a good international perspective.

2.3 Course Construction Serving the Student Population

About 40 per cent of the graduate students in the field of civil engineering at the university choose the direction of engineering materials each year to study theory, conduct scientific research and write their graduation theses. Graduate students in the structural department are mainly engaged in research and writing their graduation theses on reinforced concrete structures and composite structures, and their fundamental theories cover the basic knowledge and practical applications of cement and cement concrete. In terms of the student body in the field of civil engineering, about 80 per cent of the students are familiar with the knowledge reserve of cement and concrete. Thus, the "Cement and Concrete" course is now relatively popular with the students in the postgraduate program.

2.4 Position of the Course in the Graduate Training Program

In the direction of professional master's degree training in civil engineering at the University of Science and Technology Liaoning, the three research directions are structural engineering, geotechnical engineering and engineering materials. "Cement and Cement Concrete" is a degree-specific professional course in the direction of engineering materials. Cement is a fundamental research problem in the field of materials science and engineering, and cement concrete is an application problem that integrates materials science, civil engineering, etc. The two are at the beginning of "applied-basic" graduate education. Therefore, "Cement and Cement Concrete" will be one of the first subjects in the graduate training program.

2.5 Course Objectives of "Cement and Cement Concrete"

Knowledge Objectives: a. Systematically learn the basic theoretical knowledge of cement in class. They will know the components, structure and characteristics of cement concrete. They should be well-versed in the latest knowledge of special cements and functional concretes. They should know the industry standards, engineering specifications and sustainable development trends in the field of cement-based materials.

a. Ability Objectives: Students should be able to conduct theoretical analysis and experimental

design. They need to be able to solve engineering problems. They should be able to obtain literature and explore the limits of knowledge. Improve their expression in class and work well in a team.

Ideological and Political Goals: a. Students should be able to learn independently and have a spirit of lifelong learning. They will start the concept of green development. c. They will be more confident in life and have the will to fight. They should be able to think independently, have a sense of social responsibility, and take initiative.

3. Course Teaching Content and Resource Construction

3.1 Sequence of Knowledge Modules and Corresponding Class Hours

The "Cement and Concrete" course is worth 2 credits and has 32 theoretical class hours and ten knowledge modules. Table 1 shows the general teaching content and the division 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 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

There are many important contents and difficulties in the "Cement and Cement Concrete" course. To improve the quality of teaching, the five problems in the course are listed in Table 2 below.

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.	The definitions, classifications and main uses of cement and cement concrete need to be clarified, and a course knowledge framework should be built. One should be able to explain the functions of the parts in cement and concrete. Be aware of the engineering values and development trends in the field of low-carbon, high-performance and intelligent. Difficulty: The abstract idea is too vague. It is difficult to combine the above knowledge. It is not straightforward to connect the development of high-tech industries with basic research.	1. By reading the new textbooks in the past three years, key journal papers and classic works in the course, the teacher will expand their knowledge base, organise new knowledge and new technologies, and deepen their theoretical understanding. 2. Increase teaching efficiency by creating multimedia courseware and AI assistance, adding pictures, animations, engineering case videos, virtual simulations, etc., to expand the scope and improve the quality of teaching. 3. Organize the courses reasonably in line with the structure of the Chaoxing platform, expand the online teaching resources, build a chain of correlation for "material composition - structure - performance - application" with mind maps, create a full-course knowledge graph, and improve the integration of upstream and downstream knowledge in the courses. 4. The course will present new developments in all areas through popular cases, national development strategies, outstanding international conferences and academic papers, research hotspots, etc., and will use heuristic and discussion-based teaching methods. 5. The course will strengthen school-enterprise cooperation by having enterprise experts participate in the construction of the course and inviting them to share practical engineering problems and their solutions, as well as new technologies and new ideas from enterprises.
Module 2: Concrete Raw Materials.	The selection of cement grade, types of sand and stone aggregates, aggregate gradation and control of mud content, as well as the balance between strength and workability, all need to be well managed. Problems: Fluctuation of Material Properties and Regulation of Performance Balance. New varieties of raw materials from China and abroad have problems.	
Module 3: Concrete Admixtures.	Key points: One needs to know the mechanism of concrete admixtures, how to balance concrete performance and cost by adjusting admixtures, and what the test standards and evaluation methods are. Difficulty: The compatibility of the admixture and cement is not good. There is a problem of conflict between dosage and cost control. New varieties and technologies of admixtures from China and abroad have problems.	
Module 4: Properties of Fresh Concrete.	Learn the basic models of rheology, the workability of fresh concrete and the application of cement and admixtures. Difficulties: The basic models of rheology are not easy to learn.	
Module 5: Structure of Hardened Concrete.	Key points: One should know the composition and structure of hardened cement paste, as well as the interface of hardened concrete. Difficulty: The interface of hardened concrete is not simple to learn.	
Module 6: Physical and Mechanical Properties of Concrete.	The main points are to learn about the strength of concrete and its deformation characteristics. Difficulties: The process of microscopic failure in concrete is not well known.	
Module 7: Durability of Concrete.	One must be aware of the failure law for concrete under the combined effect of several factors. Difficulties: We do not know how to classify and recognise serious illnesses.	
Module 8: Concrete Mix Design.	The basic methods of mix design for high-performance concrete, lightweight aggregate concrete and other kinds of concrete should be learned. Difficulty: The new concepts and ways of mixing are not easy to learn.	
Module 9: Building Mortar.	We need to know the proportion of the components in the mortar. Difficulties: Dry-mixed mortar is inconvenient to prepare.	

Module 10: Fracture Mechanics Analysis of Concrete.	Key points: One should be aware of the failure and fracture modes of concrete, as well as damage mechanics. Difficulties: The fracture mode of concrete and the damage mechanics method are not well known.

3.3 Teaching Resource Construction

a. Lesson Plan Design: The teaching team has added new knowledge and new technologies, deleted old chapters, carefully studied the new textbooks of the past three years, key journal papers and classic works, organised the new knowledge and new technologies, deepened the theoretical foundation, etc.

b. Construction of Multimedia Resources: AI will be employed to add pictures, animations, engineering case videos, virtual simulations, etc., to the course to enhance the teaching effect of theory.

c. Chaoxing Course Construction: Add it to the online teaching materials, use mind maps to build the correlation chain of "material composition-structure-performance-application", build a full-course knowledge graph, and improve the integration of upstream and downstream knowledge in the course.

d. Integration of New Technologies: List cases from high-tech industries, national development strategies, top international conferences and academic papers, etc., to show research hotspots.

e. School-enterprise collaborative course construction: Enterprise experts participate in the development of courses, and these courses are designed to have practical engineering problems and solutions, as well as new technologies and new ideas from enterprises.

4. Reformation of Course Teaching Methods

4.1 Different Teaching Methods Used in the Teaching Process

a. Case Analysis Method: To organise the teaching of the basic theories in the composition design of high-performance concrete, microstructure evolution and performance relations systematically, actual engineering cases (such as corrosion protection of aqueducts and reservoirs) can be selected for analysis. Therefore, we hope to help the students better understand the problems in their studies and awaken their interest in learning.

b. Blended Teaching Model: Combine all kinds of online resources, such as multimedia courseware, videos, virtual simulations, etc., with traditional in-class teaching to increase the interest of graduate students in self-study, improve their assimilation of knowledge, and meet the demand for interdisciplinary talents in the new era of engineering education.

c. Problem-oriented teaching method: Engineering problems in the area of the Lhasa Plateau are used as motivation to have graduate students actively explore solutions and exercise their critical thinking and creativity.

d. Thematic seminars and flipped classrooms will be organised to spread the news of the new developments in special high-performance concrete, crack control and health monitoring among the public. Students need to collect relevant materials and prepare a PowerPoint presentation, and then, in front of the teacher, they will present the results of their research and be assessed by the teacher.

e. Method of Project-Based Learning and Interdisciplinary Integration: Research projects with practical applications (such as low-heat cement and green high-performance concrete) are taken as the carriers to integrate multidisciplinary knowledge of materials, structure and environment, and cultivate the independent research ability and teamwork skills of graduate students.

4.2 Implementation Process

a. The two cases of the Beijing Xizhimen Bridge and the Beijing Sanyuan Bridge will be taken as teaching materials for practical durability in this class. Beijing Daxing International Airport, the Shanghai Tower and high-speed rail in China are all representative cases of the use of high-performance concrete. The new high-performance concrete of the Hong Kong-Zhuhai-Macao Bridge is now a teaching material for concrete admixtures, physical and mechanical properties of concrete, durability of concrete, etc. Therefore, the students will be able to learn better from the

teaching cases.

b. Build a course in the blended teaching model on the Chaoxing platform, expand online teaching materials, create mind maps to build the chain of correlation among "material composition-structure-performance-application", build a full-course knowledge graph, and improve the integration of upstream and downstream knowledge in the course.

c. The problem-oriented teaching method for the structure of hardened concrete begins with a question from a pack of A4 paper: Why can the whole pack be subjected to compression, but a single sheet is easy to tear? Therefore, the students will learn to recognise the interface of the hardened concrete structure. Given that the popular topics are green building materials and low-carbon cement, I will put forward some open-ended questions, such as how to use industrial waste residue to replace traditional cement raw materials, to promote research. It also has the problem of how to reduce the carbon footprint of concrete and has drawn the attention of many people.

d. Thematic seminars and the flipped-classroom model are employed to have students carry out thematic seminars and flipped-classroom activities on new topics, such as "special concrete", and to switch from "knowledge reception" to "knowledge creation".

e. In accordance with the provincial and municipal research projects and horizontal projects organised by the university's School of Civil Engineering, project-based learning and interdisciplinary integration are employed in the project-based learning activities to foster the independent research ability and teamwork skills of graduate students. Therefore, the national energy-saving and emission-reduction policies, the strategy for sustainable development, and the idea of green development can be introduced in the classroom, and interdisciplinary learning will be achieved.

Conclusion

The construction of the graduate course "Cement and Cement Concrete" at the University of Science and Technology Liaoning is in line with the teaching philosophy of "high level, high standard", promotes interdisciplinary integration, optimizes the structure of course teaching content according to the connotations of the "1+3+2" education system reform, continually builds teaching resources, and can provide a strong foundation for graduate students to conduct research on cement-based materials.

This course has completed the construction project for the ideological and political education demonstration course, has been recognised by the university's experts, and has won the second prize in the fifth university graduate education reform research and construction achievement award. At present, no other Chinese university has published a paper on the construction of university-level ideological and political demonstrations in this course.

In the future, the teaching staff of the university will continue to strengthen and promote the "Cement and Concrete" course, pay attention to the development trends of the industry and changes in academia, promptly update the course content, improve teaching materials, and keep up with the progress and adaptability of the course. The Strategy for Empowering Teaching Reform in this course can also be applied by other universities.

Fund Projects

The 2025 annual graduate premium course construction project (funded by the Graduate Education Reform and Innovation Project) of the University of Science and Technology Liaoning is "Cement and Cement Concrete" (2025YJSCX28).

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