Teaching Reform and Exploration of the 《Material Mechanics》 Course in Civil Engineering under the New Situation

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Abstract: In the new era of construction of new engineering disciplines, construction of engineering education professional accreditation, and transformation of the intelligent construction industry, the civil engineering industry is changing profoundly towards greening, digitization and intelligence, and the demands on the mechanical modeling ability, complex engineering problem analysis ability and innovative practical ability of civil engineering professionals are increasing. "Material Mechanics" is a core basic course in civil engineering and a key link connecting basic mathematical and physical knowledge with professional structure courses. Given the serious problems in traditional teaching, such as the lack of connection between theory and engineering practice, the single-teacher teaching model, a fixed practical system, one-sided assessment and evaluation, and outdated content, this paper takes the concept of outcome-oriented education as its foundation and, in light of the talent cultivation goals for civil engineering, implements all-round teaching reform based on six dimensions: reconstruction of teaching objectives, optimisation of teaching content, innovation in teaching mode, improvement of the experimental system, diversified assessment and evaluation, and integration of course ideological and political education. Build a complete teaching system of "theoretical instruction + engineering problems + virtual laboratory + innovative activities" to correct the deficiencies of the old examination-oriented model and cultivate students' engineering mechanics thinking and job adaptability. Based on the above practice, the reform plan has successfully enhanced the teaching quality of this course, strengthened students' professional foundation, and can offer a reference for the teaching reform of basic courses in civil engineering in the new era.

Keywords: Civil Engineering; Material Mechanics; New Engineering Discipline; Teaching Reform; Intelligent Construction; Course Ideological and Political Education

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1.Introduction

With the acceleration of China's new urbanisation construction and the upgrading of the construction industry, intelligent construction, prefabricated buildings and green low-carbon building materials technology have been widely spread. The civil engineering industry has moved away from the old way of large-scale construction and entered a new period of digitalisation, optimisation and intelligence. The establishment of new engineering disciplines and the accreditation of engineering education programs clearly require that civil engineering professionals have a solid foundation in mechanics and engineering modeling skills, the ability to solve problems, innovative practical qualities, and can adapt to the demands of industry transformation and upgrading.

Therefore, in light of the special attributes of civil engineering education and the new demands for jobs in the industry, this paper will focus on the pain points in course teaching, carry out all-around and systematic exploration of teaching reform, build a material mechanics teaching system that meets the requirements of intelligent construction and new engineering discipline construction, and achieve a shift from "knowledge transmission" to "ability cultivation and value shaping" in all-round education.

2.Industry New Situation and Traditional Course Teaching Pain Points

2.1 Core Requirements of the Industry's New Development Situation

The development of the civil engineering industry at present has three main trends and thus new demands for teaching material mechanics. First, the construction of the new engineering discipline is moving forward in depth, promoting interdisciplinarity, industry-academia collaboration and cultivation of innovation ability; thus, basic

courses need to move away from a single-theory teaching model and be connected with engineering practice and the frontiers of industry. Secondly, intelligent construction has been fully realised, and many new technologies and new processes, such as BIM technology, finite element numerical simulation, 3D printing building materials, prefabricated structures, etc., have been widely applied. The new type of requirement is that civil engineers should be digitally literate. Thirdly, green and low-carbon development have become the main directions of the industry, and with the continuous application of high-performance concrete, fibre composite materials and lightweight composite structures in engineering practice, the teaching scope of traditional material mechanics is expanding. Fourthly, the accreditation of engineering education programmes is becoming more standardised and regular; thus, course teaching should precisely meet the graduation requirements and focus on cultivating students' fundamental abilities in mechanics modelling, engineering problem analysis and safety risk assessment.

2.2 Existing Problems in Traditional Teaching

2.2.1 General Teaching Cases Without Civil Engineering Features

Although the current textbooks and classroom examples focus on mechanical and general members, there are a lack of typical civil engineering components such as beams, columns, pile foundations, scaffolding, prefabricated joints and foundation pit support. Students are unable to connect mechanical theory with the structure of buildings, cannot extract mechanical models from real engineering scenarios, and as a result, there is a serious problem of knowledge disconnection and very low professional recognition of the course.

2.2.2 Focus on formula derivation; ignore the engineering physical meaning.

Traditional classes focus too much on deriving mathematical formulas and training in problem-solving, but they do not show the engineering physical significance of mechanics concepts such as stress, strain, deformation and instability. Most students learn the calculation formulas by rote memorisation; they do not understand the failure mechanism and force laws of components, and are unable to apply mechanics knowledge to explain engineering defects or optimise structural design. The sense of mechanics is weak.

2.2.3 Old teaching methods are not digitised.

Most classrooms are still using blackboards and PPTs for theoretical teaching, and digital teaching tools such as finite element simulation, three-dimensional visualisation and virtual simulation have not been introduced yet. The teaching mode is old-fashioned and does not meet the demands of digitalization and simulation in the development of intelligent construction; students lack application cognition of modern engineering analysis tools and have poor job adaptability.

3.General Teaching Reform Ideas

In line with the requirements for building new engineering disciplines and the changes in the civil engineering industry, this teaching reform is in accordance with the general educational concept of "solidifying the foundation, basing on civil engineering, integrating digitalization, strengthening practice, and fostering moral education", is guided by the OBE outcome-oriented education concept, and is based on the reverse design of professional graduation requirements and industry job demands to restructure the course teaching system. The three main changes in the reform are: First, the aim of teaching is to foster all-around engineering ability, innovation and professional qualities; Second, the form of learning will change from passive practice and acceptance to active exploration, engineering modelling and problem-solving; Third, the teaching carriers will be diversified to integrate "theory + physical experiments + virtual simulations + engineering cases". By connecting the entire teaching chain of "classroom theory - experimental practice - engineering application - innovative exploration", a material mechanics course system with the characteristics of civil engineering is established to nurture high-quality civil engineering talents in line with the needs of the industry in the new era.

4.Specific Implementation Paths for Teaching Reform under the New Situation

4.1 Reconstruct hierarchical teaching objectives, precisely aligning with the requirements of talent cultivation

Given the graduation requirements for engineering education and the demands of society for civil engineering talents, the following three successive teaching goals will be set as the foundation for the engineering and innovation stages. Achieve close correspondence between teaching aims and job requirements.

Foundation Goal: Have students learn the basic theories of tension-compression, shear, torsion, bending, combined deformation, stability of compression members and energy methods, master simple ways to test material mechanics properties, and gain some calculation skills for the strength, stiffness and stability of members.

Engineering Goals: Help students concentrate on civil engineering situations, be able to abstract mechanical calculation models from typical components such as frame beams, load-bearing columns, pile foundations, scaffolding and support structures, understand the mechanical basis of bearing capacity calculations in building structure design specifications, and have preliminary engineering mechanics problem-solving ability.

Innovative Expansion Goal: Help students first grasp the basic ideas of numerical simulation, learn about the mechanical properties of new civil engineering materials, be able to analyze the reasons for structural failure in engineering case studies, propose simple optimisation plans, and acquire innovative thinking and a sense of engineering safety.

4.2 Optimize the teaching content system, create civil engineering characteristic course resources

In response to the problem of weak professional character in the course, restructure the original teaching content into modules, eliminate redundant general knowledge, improve the applicability of civil engineering, and add frontier modules from the industry.

Convert knowledge points into civil engineering form first. Replace the general mechanical examples and exercises with specific cases from civil engineering. The axial tension-compression module is used for cases involving steel bars, prestressed bars, pile foundations, anchor rods, etc.; the torsion module is for rain shelter beams, pipe supports and other torsion problems of pile foundations; the bending module includes frame beams, floor slabs, foundation support beams, crane beams and so on; the stability of compression members module investigates the reasons for instability in scaffold uprights, steel structure columns and tower crane support columns; and the dynamic load module covers practical engineering problems such as bridge pulsating loads and fatigue failure of crane beams.

Add Industry Frontier Expansion Modules second. In line with the development trend of intelligent construction and green buildings, add elective content such as the mechanical properties of new civil engineering materials, the mechanical behaviour of prefabricated nodes, the basics of finite element simulation, and case analysis of structural failure to expand the students' knowledge horizon and connect with new industry technologies and scenarios.

Thirdly, improve the coordination of courses. Actively link with the core courses of structural mechanics, steel structure and concrete structure, clarify the foundational role of material mechanics beam models in class, organise the connection relationships among knowledge points in different courses, eliminate course barriers, and build a coherent system of professional knowledge.

4.3 Innovate multiple teaching modes, construct a virtual-real integrated classroom system

Move away from the old one-teacher lecture model and introduce case-based and project-based teaching, blended learning, digital simulation teaching, etc., to create an all-encompassing and immersive way of teaching.

Use the closed-loop teaching model of "engineering scenario introduction - mechanical problem extraction - theoretical derivation and solution - engineering result analysis - scheme optimisation and improvement". For example, in the chapter on pressure rod stability, one can use the imported cases of scaffold collapse and steel structure column instability accidents as the introduction, have students work in groups to explore the influence of

beam length, cross-sectional form and support method on the critical load, design structural reinforcement optimisation plans, and enable students to master the theory and apply knowledge in the process of exploration.

Enhance the Online-Offline Blended Teaching Model. Before the class, micro-lesson videos, engineering real-case examples and pre-class tasks will be distributed to provide a foundation for the knowledge points. During the class, key and difficult points, as well as engineering difficulties, will be pointed out and addressed through interactive discussion and model demonstration to solve the students' pre-class questions; after class, engineering exploration tasks and supplementary reading materials will be provided to extend the teaching scenario. At the same time, 3D animations and engineering short videos are used to show the whole process of stress distribution, component deformation and instability failure visually, thus solving the teaching problem of abstract knowledge points.

Introduce Digital Simulation-Assisted Teaching. Simple teaching editions of ANSYS and Abaqus are used in class to show simulation examples and present the differences in stress distribution, shape of deformation and force. By comparing the results of theoretical calculation and numerical simulation, students will learn about the differences between the two types of solutions and develop a modern mechanical analysis thinking style of "theoretical calculation plus digital simulation", meeting the training needs for intelligent construction digital talents.

4.4 Build a diversified assessment system and improve the all-round education evaluation

Do not use only one type of test for grading; set up a complete assessment system that covers both the learning process and the final test to evaluate students' learning progress, ability, all-round quality, etc. The total course score is divided into 50% process evaluation, 20% tests and 30% final exams.

Assessment of process includes classroom interaction, group case discussions, after-class homework, experiment reports, exploration tasks in simulations and online learning, etc.; it aims to find out students' learning attitudes, teamwork ability and engineering exploration ability. At certain times, basic knowledge points and simple applications of mechanical models will be tested, and if there are any deficiencies in the learning effect at that time, they will be promptly corrected. The latest revision has changed the distribution of all kinds of questions, reduced the proportion of simple formula-and-calculation problems, and increased open-ended questions such as engineering modelling, component force analysis, engineering case studies and scheme optimisation. Therefore, the current aim is to determine how well students have learned the mechanical knowledge and how to use this knowledge in engineering practice. With this diverse assessment system, the focus will no longer be solely on "evaluating problem-solving ability", but rather on evaluating "all-round engineering literacy", motivating students to learn daily knowledge systematically, apply it in practice, and study freely without the pressure of exams.

4.5 Deeply integrate course ideological and political education to implement the fundamental task of fostering virtue and cultivating talents

Based on the knowledge points of the course and engineering cases, explore in depth the ideological elements of the civil engineering major to achieve the integration of knowledge inheritance, ability development and value education. Combine the failure cases of components and the engineering collapse accident to improve students' awareness of engineering safety and responsibility, establish the professional bottom line of "safety first, quality first", explore the mechanical wisdom behind classic projects such as the Hong Kong-Zhuhai-Macao Bridge and super projects, strengthen students' professional confidence and patriotism, integrate rigorous academic research, breakthrough and difficult-problem-solving stories of mechanical scientists to cultivate students' pragmatic and meticulous craftsmanship spirit, combine green buildings, new urbanization construction and infrastructure upgrading industry missions to guide students to develop a sense of responsibility and commitment to the industry, serve public infrastructure and serve the country, thus nurturing well-rounded new-era civil engineering talents.

5.Conclusion and Outlook

Given the new circumstances of new engineering construction and the changes in the intelligent construction

industry, the old mode of teaching material mechanics is no longer suitable for the new demands of civil engineering professional talent education. Based on the teaching pain points of the course and the requirements for jobs in the industry, we have restructured the layered teaching objectives, optimised the teaching content according to the characteristics of civil engineering, introduced various integrated teaching models, improved virtual and real combined experimental systems, strengthened diversified assessment and evaluation, deeply integrated ideological and political education into the course, and built an all-round and systematic course teaching reform system. The reform has solved the problems of the theoretical-engineering gap, weak application education and rigid teaching models, strengthened students' mechanical modelling ability, improved their engineering problem-solving skills and innovative practical literacy, and raised the overall quality of course education.

In the future, the integration of industry and education will be further strengthened in teaching. Real engineering detection and structural optimisation projects carried out by enterprises will be added to the teaching materials. An intelligent individualised supplementary teaching model will be established to meet the various learning needs of all students. The frontier of new building materials, prefabricated buildings and urban renewal will continue to develop and provide new teaching materials. The educational support role of the basic course in material mechanics will continue to be carried out to foster more high-quality, multi-skilled and innovative engineering and technical talents for the civil engineering industry.

References:

[1] Ministry of Education.Action Plan for New Engineering Disciplines Construction[Z].2017.

[2] China Engineering Education Professional Accreditation Association.Engineering Education Accreditation Standards(2022 Edition)[S].2022.

[3] Liu Hongwen.Materials Mechanics[M].Beijing:Higher Education Press,2020.

[4] Sun Xunfang.Materials Mechanics[M].Beijing:Higher Education Press,2019.

[5] Chen Leilei,Li Jiaqi,Gu Chengjun,et al.Exploration and Practice of the Teaching System of Materials Mechanics under the New Engineering Discipline Background-Taking the Civil and Transportation Major as an Example[J].Higher Architectural Education,2024,33(4):76-83.