

Original Paper

The Teaching Reform Path and Practical Exploration of Soil Mechanics Course under the Background of AI Empowerment

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Abstract

As a compulsory core basic course for civil engineering majors in civil engineering schools, soil mechanics undertakes the teaching function of connecting basic mechanics theory with geotechnical engineering field practice. The course itself has the dual attributes of abstract theoretical derivation and engineering application. In the long-term first-line teaching process, it is found that the traditional classroom solidified teaching mode is difficult to adapt to the current talent training needs. One-way theoretical teaching, the disconnection between theoretical content and engineering site, the single level of practical training, and the one-sided assessment and evaluation standards continue to restrict the effect of classroom education. After two rounds of practice in the whole teaching cycle, this reform has alleviated the teaching problem of the separation of theoretical knowledge and engineering application to a certain extent. The comprehensive ability of students to analyze geotechnical engineering problems independently, classroom workshop hands-on test and numerical simulation modeling has been significantly improved. The optimization idea formed in this study is only applicable to the teaching scene of civil engineering specialty in local application-oriented undergraduate colleges. Colleges and universities with different school-running levels and different regional geological characteristics still need to adjust and optimize their own school-running conditions when drawing lessons from them. The practical scheme formed can provide reference ideas for the teaching optimization of similar engineering basic courses.

Keywords

Artificial intelligence, soil mechanics, teaching reform, smart classroom, practical teaching, new engineering

1. Introduction

The scale of urban and rural infrastructure construction in China has been steadily expanding. New engineering scenarios such as mountain geotechnical engineering, urban underground space development, and coastal soft soil foundation treatment are constantly emerging. New technologies such as geotechnical investigation, intelligent monitoring, and digital simulation are rapidly spreading. The industry's evaluation criteria for the comprehensive ability of civil engineering graduates have changed significantly compared with ten years ago. The concept of new engineering education takes moral education as the fundamental task, emphasizing achievement orientation, interdisciplinary, and school-enterprise collaborative education. The teaching of engineering courses needs to keep up with the pace of industrial technology iteration, focusing on training applied technical talents who can cope with complex engineering problems and have innovative thinking.

The course content of soil mechanics mainly focuses on the mechanical properties of soil permeability, deformation and strength. The relevant theories are the core basis for the design and construction of geotechnical engineering such as foundation, slope support and roadbed design. The internal formula derivation of the course is complicated, the mechanical mechanism is abstract, and it is highly dependent on the accumulation of field engineering experience. It is a typical course with deep binding of theory and practice. The degree of students' understanding of soil mechanics knowledge will directly affect the learning effect of subsequent geotechnical engineering series of professional courses, and will also determine the quality of investigation, design, site construction and other work after students enter the job.

The soil mechanics course of the author's college has long followed the traditional offline blackboard teaching mode. The update speed of the textbook content lags behind the development of industry technology. The focus of classroom teaching is biased towards formula derivation, and lacks the expansion content combined with the current new geotechnical engineering scene. The classroom teaching is mainly based on the one-way output of teachers, and there is a lack of normalized discussion and communication between teachers and students; the campus practice is mainly based on basic verification tests, and the digital simulation and comprehensive engineering training sections are insufficient. The final written test scores account for a high proportion in the total score of the course, and the ability performance of the whole process of learning is difficult to be included in the evaluation system. Long-term use of this kind of teaching mode, many students can only rely on rote learning to cope with the exam, it is difficult to independently use the theory of soil mechanics analysis of real engineering.

2. The Practical Problems Existing in the Traditional Soil Mechanics Course Teaching

2.1 The Update of Course Content Is Lagging Behind, and There Is a Disconnection between Knowledge System and Industry Development

At present, the revision period of general soil mechanics textbooks in most colleges and universities in China is long. The overall knowledge framework takes the classical soil mechanics theory as the main body. The basic contents of soil physical index test, seepage stability, foundation settlement calculation, soil shear strength and so on occupy most of the space. In recent years, the digital survey, intelligent monitoring of soil and new soft soil reinforcement technology in geotechnical industry have been rarely included in the teaching category. In the process of classroom explanation, teachers mostly promote teaching in accordance with the order of chapters and sections of teaching materials. The space for expanding the explanation of on-site disease inducements and engineering disposal schemes corresponding to knowledge points is limited, and it is difficult for students to establish the relationship between theoretical formulas and engineering sites.

The division of knowledge points in each chapter of the course is relatively independent. In the teaching stage, the internal logic between the contents of different chapters is rarely sorted out. It is difficult for students to build a complete thinking of geotechnical mechanics analysis. In the face of multi-factor coupling comprehensive engineering problems, there is a general lack of complete analysis ideas. Simplifying pure mathematical derivation, supplementing the content of cutting-edge technology in the industry, and reconstructing the teaching content in combination with regional geological cases are the first problems to be solved in optimizing the soil mechanics classroom.

2.2 The Classroom Teaching Mode Is Solidified, and the Teaching of Abstract Knowledge Points Is Difficult

The traditional soil mechanics classroom generally adopts the teaching form of teachers' blackboard writing with static PPT. The whole class is mainly based on one-way explanation of theoretical knowledge, and lacks diversified classroom interaction design. The core contents such as the principle of effective stress, the consolidation process of soil and the shear failure of soil are highly abstract. It is difficult to visually present the dynamic change process of soil stress, deformation and instability by static pictures and texts. Students can only mechanically memorize formulas and definitions, and cannot understand the physical connotation behind the mechanical mechanism.

The classroom lacks interactive links such as group discussion, dismantling of engineering cases, and exploration of in-class problems. The overall interest of the classroom is insufficient. Many students are in a passive listening state, and their willingness to explore knowledge independently is weak. The single curing teaching method continues to reduce the classroom absorption efficiency. How to use digital and AI teaching tools to visually display the process of soil mechanics change and change the classroom mode of one-way infusion has become the key difficulty of this teaching reform.

2.3 There Are Multiple Shortcomings in the Practical Teaching Link, and the Integration Effect of Theory and Practice Is Limited

Practical teaching is the key carrier to open up the theoretical knowledge of soil mechanics and the engineering site. There are many obvious shortcomings in the original practical teaching system of our school. The on-campus experimental projects are mainly based on confirmatory basic tests such as moisture content, liquid-plastic limit, direct shear test, etc. The number of comprehensive and innovative tests that require students to design their own schemes and deal with abnormal test data is very small. Students can only complete the test steps in accordance with the standardized operation process, and their ability to analyze and design independently is not fully exercised.

2.4 The Assessment and Evaluation System Is Biased Towards Examination, and the Whole Process Ability Is Missing

The original soil mechanics course assessment adopts the final written examination as the main and the usual performance as the supplement, and the final evaluation mode. The paper score accounts for more than 70% of the total score of the course. The assessment questions focus on concept recitation and basic formula calculation. It is difficult for students to objectively judge their engineering thinking, simulation modeling ability and on-site problem handling ideas through a test paper. The usual scores only rely on classroom attendance and after-school written assignments. The assessment dimension is single, the scoring criteria are lack of unified norms, and the evaluation results are highly subjective.

The exam-oriented assessment mechanism will guide students to form a learning habit of emphasizing the end of the term, neglecting the process, emphasizing theoretical recitation, and neglecting practical operation. Many students focus on recitation formulas before the exam, ignoring experimental operations and case analysis learning tasks throughout the course, and the final assessment scores cannot truly reflect students' comprehensive engineering literacy. There is a conflict between this evaluation system and the education orientation of new engineering with ability cultivation as the core. It is an indispensable part of this teaching reform to construct a multi-evaluation mechanism covering the whole process of pre-class, in-class, after-class and practice.

2.5 Curriculum Ideological and Political Integration Is Superficial, and the All-Round Education System Has Not Yet Taken Shape

In the past, the classroom teaching of soil mechanics focused on the explanation of professional knowledge, and the ideological and political content and professional teaching were in a state of mutual separation. It was rarely combined with major geotechnical engineering cases, industrial safety accidents, and green geotechnical construction concepts to excavate ideological and political teaching materials. Civil geotechnical engineering is directly related to the safety of people's lives and property and the regional ecological environment. The sense of responsibility, professional ethics, innovative spirit and ecological protection thinking of industry practitioners need to be cultivated for a long time by relying on the course.

If the professional classroom lacks normalized ideological and political infiltration, it is difficult to implement the complete trinity education goal of “knowledge imparting, ability training and value shaping.” Most of the existing classroom ideological and political integration methods are short oral preaching at the end of the class, which are not deeply bound to the core knowledge points such as soil stability, foundation safety and slope treatment, and the effect of educating people is very limited.

3. The Overall Idea of Teaching Reform of Soil Mechanics Course under AI Empowerment

This teaching reform is based on the school-running orientation of the applied undergraduate civil engineering specialty of our school, with the fundamental goal of establishing morality and cultivating people, relying on the concept of result-oriented education, combined with the intelligent teaching tools of artificial intelligence, and aiming at all kinds of classroom teaching problems sorted out above. The reform content covers the reconstruction of curriculum content, the construction of intelligent classroom, the construction of hierarchical practice system, the improvement of multiple assessment, and the deep integration of curriculum ideology and politics.

Five core implementation guidelines are followed in the implementation of the reform plan. The teaching content adjustment stage fully fits the training program of civil engineering professionals, and closely follows the digital and intelligent development trend of geotechnical industry to reconstruct the knowledge framework. In the implementation stage of teaching, the boundary between theoretical classroom and practical teaching is broken, and the deep integration of online autonomous learning, offline theoretical intensive teaching, on-campus simulation experiment and off-campus field training is promoted. The classroom design highlights the dominant position of students in the whole process, weakens the one-way output mode of teachers, and stimulates students' enthusiasm for independent inquiry with the help of AI-assisted teaching tools. The teaching carrier fully introduces digital and artificial intelligence teaching resources, and expands the classroom teaching scene based on AI simulation, intelligent question answering and virtual experiment. In the education link, the ideological and political elements are infiltrated into the whole process of pre-class preview, in-class discussion and after-class practice, and the professional knowledge teaching and value concept guidance are completed simultaneously.

4. The Specific Implementation Path of AI-Enabled Soil Mechanics Course Teaching Reform

4.1 Reconstruct the Hierarchical Modular Teaching Content and Integrate the Cutting-Edge Knowledge of AI Geotechnical Simulation

Aiming at the problems of lagging content, fragmentation of knowledge points and insufficient engineering application of the original teaching materials, combined with the needs of enterprise geotechnical post ability, the four-layer modular curriculum knowledge system is reconstructed based on AI digital geotechnical industry resources, and the theoretical content of old repetition and

engineering practice is deleted synchronously.

The basic layer module focuses on the necessary contents of the course. The contents of soil composition, physical index classification and basic seepage theory are arranged in the early stage of the course, which consolidates the students' basic cognition and paves the way for the follow-up study of complex mechanics. The core layer module is developed around the core requirements of engineering design. The contents of foundation stress settlement, soil shear strength, soil pressure calculation, slope stability checking, foundation bearing capacity determination and so on are combined with the principle of disassembly mechanics of real engineering cases, weakening the pure mathematical derivation of complex formulas, focusing on the physical connotation, applicable boundary and field use scenarios of formulas. The expansion layer module combines the characteristics of local geotechnical engineering, supplements the common engineering scene contents such as foundation pit support, soft soil foundation treatment and road subgrade disease treatment, analyzes the formation mechanism of various geological diseases and corresponding construction control schemes, and narrows the distance between classroom theory and site.

4.2 Relying On the AI Intelligent Teaching Platform, Build an Online and Offline Closed-Loop Hybrid Classroom

With the help of rain classroom, learning through intelligent teaching platform, AI simulation and AI micro-course generation tools, the whole process closed-loop intelligent classroom of pre-class independent preview, in-class interactive intensive teaching and after-class personalized expansion is constructed, and the traditional offline single teaching mode is changed.

In the pre-class stage, teachers use AI tools to generate dynamic micro-courses for soil consolidation and seepage failure, synchronously push knowledge courseware, preview exercises, and engineering case materials to the online platform, and arrange layered preview tasks. Students rely on AI Q & A assistants to sort out basic knowledge points in advance, independently mark mechanical content that is difficult to understand, and the online platform automatically summarizes students' high-frequency questions to provide data support for accurate offline classroom teaching. Long-term adherence to the learning habits that can exercise students' self-sorting knowledge and actively explore problems.

In the middle stage of the lesson, the one-way explanation mode of the whole lesson is completely abandoned, and the key and difficult points of the classroom are locked according to the feedback of online preview. Case disassembly, group problem discussion, AI simulation dynamic demonstration, and in-class exercise mutual evaluation are adopted. Various forms of interspersed teaching. Combined with typical engineering accidents such as foundation pit instability and uneven settlement of foundation, thematic analysis is carried out. With the help of AI three-dimensional simulation model, the whole process of soil stress and deformation is dynamically displayed, and the teaching difficulties of abstract contents such as effective stress and shear failure are intuitively solved. Group inquiry activities are organized around comprehensive geotechnical engineering problems. Students are

grouped to complete mechanical mechanism analysis and disposal scheme design. Achievement sharing and mutual evaluation are carried out synchronously in the classroom, and logical thinking and teamwork ability are trained synchronously.

4.3 Build AI Simulation + School Experiment + School Enterprise Training Layered Practice Teaching System

In terms of practice, the school has increased cooperation with local geotechnical enterprises and survey and design institutes to form a cooperative unit or student internship platform, build a stable off-campus training platform for students, and regularly organize students to carry out on-site observation and post internships in subgrade, foundation pit and slope engineering projects under construction. Close contact with intelligent monitoring equipment and digital survey instruments on-site use process. Inviting senior engineers of enterprises to join the school to carry out special lectures, combined with real projects to explain the key points of AI geotechnical monitoring and intelligent modeling technology, both schools and enterprises to participate in practical teaching guidance, and break through the barriers between classroom theory and engineering site.

5. Reform Implementation Effect, Limitations and Future Prospects

The AI-enabled soil mechanics teaching reform program has been fully implemented in the two civil engineering classes of our school. Compared with the teaching data before the reform, significant changes can be found. The students' participation in class active questioning and group discussion has been significantly improved. They can independently use AI simulation software to complete the modeling and analysis of small and medium-sized geotechnical engineering. In the face of comprehensive engineering cases, the independent analysis ideas are more complete; in the final examination, the average score of case analysis questions was significantly improved. After students entered the enterprise internship, the speed of digital geotechnical tools was better than that of previous students who did not participate in the reform. The complete reform plan effectively alleviates the long-standing teaching problems such as obscure theory, weak practice, one-sided evaluation, and insufficient integration of ideological and political education in the traditional soil mechanics classroom. A complete teaching closed-loop is formed between the theoretical classroom, digital simulation practice, and off-campus engineering training. Students' engineering thinking, digital practical ability, and professional responsibility literacy have been synchronously improved, which is in line with the training orientation of new engineering compound civil engineering talents.

There are still some limitations in this study. The implementation of school teaching reform is highly dependent on AI intelligent teaching platform and hardware support of geotechnical numerical simulation software. It is difficult for colleges and universities with insufficient investment in laboratory digital equipment to completely reproduce the whole implementation path. The teaching case only relies on the geological scene of local soft soil and hilly slope, and the direct application of

regional colleges and universities with different geological conditions will have the problem of insufficient adaptability. AI simulation training hours are limited and cannot cover all the practical training of complex geotechnical engineering models. There is still room for improvement in the depth of students' digital modeling. Subsequent teaching optimization can be continuously promoted from two directions. Expand the AI geotechnical training hours, develop a lightweight AI simulation applet suitable for the basic teaching of soil mechanics, and reduce the threshold of software operation; jointly build a regional characteristic geotechnical AI teaching case library with multiple application-oriented undergraduate colleges of the same type to enrich the teaching materials of different geological scenes; improve the school-enterprise joint assessment mechanism, introduce enterprise engineers to participate in the evaluation of students' practical results, and further narrow the gap between classroom teaching and industry job requirements.

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