Study on the Teaching Reform of Concrete Structural Design Principle under the Application-oriented Talents of Civil Engineering

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Abstract. Due to the issues of weak practical ability of students, ineffective curriculum teaching, this paper attempts to make a preliminary reform on concrete structural design principle course for undergraduate colleges based on the shortcomings of the course of concrete structural principle design: after reform, students will become as the main body of teaching link. Starting from the pathway of theory and practice and bring students into the lab and let them participate in scientific research activities to enrich their practice ability through optimizing the blackboard teaching pattern and introducing the new media supplementary teaching for enhancing the teaching efficiency. Our school also implemented the teaching activities of concrete structure design principle under the new mode for undergraduate students in 2015 and 2016. The students' achievements and practical ability have been improved to a certain extent and good teaching results have been achieved. The authors try to provide some suggestions for the teaching reform of concrete structural design principle course in undergraduate colleges.

1. Introduction

Concrete structural design principle is a core module of civil engineering and other related courses. This course normally starts from the third year of undergraduate courses and its content involves the mechanical performance of concrete structure materials, structure design method, the basic components of section design principle, the principle and method of structural requirements and concrete durability design, etc. [1-4]. The teaching objective is to enable students to master the basic concepts, basic theories and structural requirements of concrete structures, and to apply relevant design codes to design and calculate the structural components of buildings, so as to lay a foundation for the subsequent study of concrete structure design and other specialized courses, as well as the training of compound professional technical talents in survey, design and construction management [5-6]. This course plays an important role in the whole course system of civil engineering. It is not only a summary of several early courses, but also a foundation for subsequent design courses such as concrete structure design and high-rise building structure design.

As a professional and practical course, the characteristics of concrete structural design principle course can be summed up as "five more", that is, more concepts, more principles, more involve, more formulas, more provisions; Moreover, due to the complexity of concrete structural materials and the comprehensiveness of practical application, the requirements for structural construction are complicated leading to the appearance of semi-empirical and semi-theoretical formulas and non-
uniqueness of structural design. Therefore, these issues increase the difficulty of learning the concrete structural design principle course[7-8]. According to the traditional teaching methods, it is difficult to mobilize the enthusiasm of students to learn and easy to make students bored.

Aiming at the problem of concrete structure design principle of course both at home and abroad, the implementation of the CDIO engineering education model [9-10], the introduction of engineering case teaching[11] and real model[12], strengthening the implementation of practical links[13], has achieved a certain effect. However, relevant research also pointed out that the reform of the concrete structural design principle is not a one-off event and should be selected according to the school background and students’ needs.

In the course of teaching civil engineering major students of Zhejiang University Ningbo Institute of Technology, the author observed that most students thought the course was "hard to learn", where such emotions would affect the learning mentality of the next class of students in advance. This implies that the curriculum reform of traditional model is not very well adapted to the needs of students. Therefore, how to change this situation, fully mobilize students' interest in learning, and help students deeply understand the basic content, calculation and design methods is the difficulty and focus of the teaching reform of concrete structural design principle.

2. Teaching Status of Concrete Structural Design Principle

The concrete structural design principle teaching proceeds from the aspects of theory and practice curriculum promoting the practice via grasping the theory. Considering the practice proof theory as the central thought, which conducts an analysis on the present teaching situation.

2.1. Theoretical Teaching Problems
(1) Bad classroom display effect
The traditional teaching method of the theoretical course of concrete structural design principle consists of teacher, medium and students. Medium is mainly composed of blackboard teaching or complete multimedia way, students listen passively under the platform, often need to copy the corresponding knowledge point, time-consuming for students to understand and the teaching effect is poor. It also shows that the use of multimedia to teach the concrete structural design principle does not significantly improve the quality of course teaching.

The main reason for this phenomenon is a combination of multiple subjects, complicated and abstract contents. Besides, the concrete component design is unique owing to some empirical formulas and corollaries in the actual design process. Students who are used to think and analyze the problems with the unique thinking of previous mechanics often find it difficult to accept. At the same time, in the traditional teaching mode, the teacher is the leader of classroom teaching, and the students' learning results mainly come from the lectures. Under the blackboard teaching, the theories are boring, the formulas are numerous, the calculation is complicated, and the classroom lacks interaction. Therefore, the students gradually lose the motivation and confidence to learn this course well.

(2) Lack of logic for teaching process
The course of concrete structure design principle mainly involves "concrete structure design code" (GB 50010-2010), but the author found that some teachers explained according to the old code in the teaching process, which caused some confusion to students. In the course of teaching, students often ask the meaning of the normal section bearing capacity under eccentric compression load, whereas they do not realize that the new standard has been changed from \( e = \eta e_c + \frac{h}{2} - a \) to \( e = e_c + \frac{h}{2} - a \).

Furthermore, "Unified standard for reliability design of building structures" (GB50068-2018), states that the partial coefficients of constant loads are adjusted from 1.2 to 1.3, and the partial coefficients of live loads are adjusted from 1.4 to 1.5. These changes in the data will have a greater impact on the answers and data of traditional exercises. The new standards have been amended for the structural schemes, bearing capacity, normal use limit state check, and concrete durability of concrete structures. The corresponding formulas in the traditional specification
ns do not meet the needs of production and life at this stage. Therefore, the teachers should distinguish and closely monitor the changes in the standards and inform the students regarding the changes timely.

Table 1. "Unified standard for reliability design of building structures" GB50068-2018 Load Item Coefficient Table

| Partial coefficients of loads | Applicable situation | When the effect is unfavorable to the bearing capacity | When the effect is favorable to the bearing capacity |
|-----------------------------|---------------------|-----------------------------------------------------|--------------------------------------------------|
| \( \gamma_G \)             | 1.3                 | \( \leq 1.0 \)                                      | 0                                                |
| \( \gamma_Q \)             | 1.5                 |                                                     |                                                  |

(3) Part of the teaching content is half empirical and half theoretical
Concrete structures have gone through the development process from the complete empirical method, to the allowable stress method, to the damage stage design method, and to the critical stress state design method. Structural design theory has always been closely related to practice[14-15]. Most of the calculation formulas in the course of concrete structural design principle are based on experimental research and obtained from equilibrium principle or regression analysis. Therefore, many formulas are a collection of empirical statistics and experiments, which contain a large number of revision coefficients.

The principle of existing reinforced concrete cannot be fully explained by the theoretical analysis and thus, the course also includes many structure regulations: based on the practice in setting up the steel bar. For example, bent-up bars outside the end anchorage length shall be maintained, its length in tensile region should not be less than 20d, and should not be less than 10d in compression area, a beam on both sides of the bottom bars should not turn up. Among them, the explanation of "10d", "20d" and other knowledge often makes it difficult for students to have specific practical concepts of engineering.

2.2. Practical Teaching Problems
At present, the experimental teaching of "concrete structural design principle " course in most undergraduate universities in China mainly focuses on the test of reinforced concrete structure, which mainly consists of experimental study on bending performance of normal section of reinforced concrete beam and shear capacity test of simply supported[16-17]. Since this test is a confirmatory test, the design of test scheme, specimen production, experiment preparation, specimen installation and observation instrument installation are all completed by laboratory professionals. Students only need to observe the failure sections and the test results, and record the test data.

In the above teaching mode, students have little hands-on operation and accept the knowledge passively. In addition, some colleges lay emphasis on theoretical classroom teaching for the course of concrete structure principle and ignore experimental teaching. As a result, the funding of test equipment is insufficient and test instruments are backward, which cannot play the due role of practice[18-19] and cannot meet the training requirements of practical talents. Therefore, the teaching reform of the experimental teaching part of concrete structure design principle course is extremely urgent.

3. Teaching Method Reform of Concrete Structure Principle

3.1. Optimize the Traditional Board-based Teaching Mode
Although the traditional teaching style has certain limitations, its advantages are also evident. It can ensure the initiative, real-time and coherence of teachers to teach knowledge, and can systematically impart knowledge to students in a short period[20-21].

Throughout the teaching process, for the key difficulties in the course content, such as the formula derivation and calculation of the concrete component section design, the traditional teaching method (i.e. black board) can be used. The teacher first writes the formula principle on the board and makes a
part. Then, calculate the sketch and guide the students to derive the basic formula for the calculation based on the equilibrium conditions. The block diagram of the step of settlement of the normal section of the single reinforcement rectangle girder section flexural members shown in Fig. 1 can help students deepen their understanding of the derivation process, and systematically understand the calculation steps, helping students overcome the concrete problems.

\[
\begin{align*}
\alpha_s &= \frac{M}{\alpha_1 f_c b h_0^2} \\
\xi &= 1 \sqrt{1 - 2\alpha_s} \\
A_s &= \xi b h_0 \frac{\alpha_1 f_c}{f_y} \\
M &= \text{bending moment} \\
\alpha_1 &= \text{coefficient of moment of section resistance} \\
f_c &= \text{design value of axial compressive strength of concrete} \\
f_y &= \text{design value of ordinary reinforcement strength} \\
b &= \text{section width} \\
h_0 &= \text{the effective height of section} \\
\gamma_s &= \text{internal moment arm coefficient of section} \\
A_s &= \text{rebar cross-sectional area}
\end{align*}
\]

**Figure 1.** Block diagram of the step of settlement of the normal section of the single reinforcement rectangle girder section flexural member.

3.2. Introduction of Multimedia Teaching Methods

Students can be impressed by the use of slide shows or case presentations when some of the textual content in the course is relatively large, the amount of information is relatively large, or some complex structure of the textbook is difficult to express clearly. Teachers should pay attention to the students' understanding of the content for the course, make the complicated and abstract things more visual and easier for students to understand. Especially for the stress and damage process of concrete members, it is often difficult to describe applying the traditional teaching methods. The introduction of animation or case video can achieve unexpected results. For some chapters with less calculation and more conceptssuch as the performance of materials for concrete structures, crack deformation and durability of reinforced concrete members. Teachers can guide the students to self-integrate some chapters and organize study groups to produce courseware.

Table 2 takes ‘Concrete Structural Design Principle’ (Shen Pusheng, 2007) as an example, and points out the content of the courseware report that can be arranged for students in the corresponding course chapters.

**Table 2.** Corresponding chapters of the theoretical course and student courseware production table.

| Course chapter | Study group report |
|----------------|--------------------|
| Chapter 1: Material properties for concrete structures | Development status of concrete materials, material properties |
| Chapters 2-6: Different Forces and Calculations of Reinforced Concrete | Case analysis of related force members and accident engineering |
| Chapter 7: Cracks, Deformation and Durability of Reinforced Concrete Members | Concrete crack detection and repair technology |
| Chapter 8: Design of Prestressed Concrete Members | Research status and application advantages of prestressed member |
Appendix section Improvement of reinforcement anchorage technology, research on concrete protective layer

The organic combination of lecturing style and modern multimedia can not only broaden students' knowledge scope, but also enable students to grasp the basic content of teaching. Fig.2 illustrates the reform measures of concrete structural design principle, it effectively addresses the problem that the teacher only teaches and the students to accept passively, enables the students to master the learning content in a lively learning atmosphere, and broadens their learning horizon. Thus, students could have a more rational understanding of the "concrete structural design principle" course.

Figure 2. Reform measures of concrete structural design principle.

3.3. Students' Comprehensive Ability (Thinking and Practical Ability) Training

Students' comprehensive ability is composed of independent thinking ability and practical ability. The teaching of concrete structure design principle should not be limited to the content in the textbook. In the actual work, they need to contact with a variety of specifications, standard atlas, professional books and so on. Therefore, for some questions with strong new concepts for students, teachers can give introductory answers, not directly give the right answers, but let students independently consult the norms before answering. At the same time, teachers should pay attention to the integration of norms in the teaching, combine with the norms of theoretical design and calculation methods. Practical teaching is an important part of the course of concrete structure design principles, which is complementary to theoretical teaching [17, 22-23], and should also increase the weight of practical operation in student assessment. At Zhejiang University Ningbo Institute of Technology, the author is working as a number of laboratories which are mainly geotechnical and road engineering laboratories, structural and bridge laboratories with a total area of over 6000 square meters. Over 1300 instruments and equipment are designed for the students' innovative experiment courses, and carrying out college students' innovative entrepreneurial project, which can provide a good platform, personnel training and support of civil characteristics.

Under this experimental condition, according to the corresponding instruments, the students are guided to conduct reinforcement binding, concrete mixing and pouring, maintenance and observation of cracks in the beam under compression (see Fig.3). Teachers should play a guiding role in students' operation and answer students' questions. At the same time, students are encouraged to actively participate in the national college students' innovation and entrepreneurship training program, which greatly expands their practical ability and consolidates the concrete structure principle course.
4. Conclusion

Based on the disadvantages of concrete structural design principle of undergraduate course colleges, starting reform from the theory and practice, optimizing the teacher blackboard writing teaching model, introducing the theory of the new media supplementary teaching in order to enhance teaching efficiency, and bring students into the lab for field operation and to participate in college students' scientific research activities to enrich students' practice ability.

Table 3. Change of students' situation after teaching reform.

| Inspection criteria       | Before the implementation of teaching reform | After the implementation of teaching reform |
|---------------------------|---------------------------------------------|-------------------------------------------|
| Course results            | Poor, average score 74.5/100                | Good, average score 83.7/100              |
| Professional skills mastery | Poor                                      | Good                                       |
| Practical ability         | Poor, dare not show on stage               | Good, dare to show                         |

At the same time, our school also implemented the teaching activities of concrete structure design principle under the new mode for undergraduate students in 2015 and 2016. The students' achievements and practical ability have been improved to a certain extent and good teaching results have been achieved (Table 3). It can also be proved that the above-mentioned teaching reform can obviously improve students' learning effect and help cultivate applied civil engineering talents. The student sample will be further increased in the future.

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