Teaching Effect Analysis of the 'Prefabricated Concrete Structure' Course Based on Building Information Modeling

https://doi.org/10.3991/ijet.v18i03.37195

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Abstract—The prefabricated building course is a highly theoretical and practical specialized course with strong professionalism and extensive teaching contents. The teaching of prefabricated concrete structures is a significant link in prefabricated building construction and an important direction of cultivating talents applied to prefabricated building construction. Previous teaching features single teaching models, focuses on teaching materials, and highlights theoretical teaching, resulting in students' low learning initiatives and poor practical ability. In order to improve the teaching effect and students' practical ability, Building Information Modeling (BIM) simulation technology was integrated into the teaching and practice of the prefabricated building courses. Then, the three-stage (guidance of real-scene cases, practical operation based on division of project work, and drawing cross-review) course teaching approach was proposed. With the construction of a prefabricated concrete structure in Hefei Metro of China as an example, students were asked to perform component modeling, assembly, and construction simulation via BIM. Results show that the teaching contents are completed, and the teaching effect is evidently strengthened. Students' abilities to understand, analyze and practice actual engineering problems are evidently improved, and their problem-solving and practical ability in the aspect of prefabricated buildings is cultivated.

Keywords—prefabricated buildings, deepening teaching, BIM technology, prefabricated components

1 Introduction

Prefabricated buildings, as a new type of building structural form, are characterized by energy conservation and environmental protection, excellent greenness and efficiency, and a high degree of industrialization, thereby becoming an important path and effective means of architectural industrialization. Moreover, prefabricated buildings have grown into an important development direction of the building field. Prefabricated buildings are welcoming a brand new rapid development phase, bringing about great demands for various talents specialized in design, production, and construction.

Colleges and universities in various areas have started the talent training reform of prefabricated buildings, especially the talents dedicated to prefabricated building deepening design, to solve the talent demands of the prefabricated building industry [1–2]. Different from the traditional building design, the prefabricated building deepening design is a multi-specialty integrated design that is further refined based on traditional construction drawings, along with the feature of high industrialization.

Many colleges and universities, especially application-oriented universities and higher vocational colleges, have launched the talent training reform of prefabricated buildings according to the local development needs for architectural industrialization [3], carried out university-enterprise collaborative talent cultivation [4], and highlighted the course teaching during cultivation. However, courses on deepening teaching, practice and design ability cultivation in the field prefabricated buildings are few, and the relevant teaching materials and models are not perfect yet. Hence, continuously improving the talent cultivation models in aspects of prefabricated building deepening teaching, practice and design by relying upon the course reform and construction is necessary.

2 State of the art

Intelligent construction has become an inevitable development trend of the construction industry as social informatization deepens. Building Information Modeling (BIM) is an important technology and means of realizing intelligent construction, with its relevance and well recognition in the industry. Domestic and foreign educators have fully recognized the importance of BIM to practical ability cultivation [5] and explored BIM-based teaching from aspects of course teaching and practical teaching.

In European and American countries, the emphasis is laid on the perfection of the BIM course system, course content setting, and teaching organization. For example, Auburn University has found in its BIM teaching practice that systematic curriculum setting is more effective than establishing a single BIM course. Purdue University has constructed a BIM course system centering on computer technology and construction technology and highlighted the cultivation of students' BIM data management and control ability. AliKN [6] provided a BIM learning result matrix, analyzed the deserved BIM ability from different industries, and mastered the BIM standard and method to cultivate cooperative ability and operation ability, as well as the BIM collaboration tool, with software evaluation and selection abilities. Fernanda [7] proposed that the construction management course should facilitate students to master the BIM applications in different project phases and gain the ability of construction management optimization on this basis. Espinoza et al. [8] studied the applications of virtual reality and BIM in sanitary engineering course teaching, and believed that their study results can help in the implementation of the pipeline engineering course in the civil engineering specialty. Brok-bals [9] suggested that institutions of higher learning should strengthen the teaching exploration into interdisciplinary BIM projects.

Studies in China lay particular emphasis on BIM curriculum setting [10, 11] and teaching organization [12, 13] and are partial to theoretical studies, whereas the BIM teaching approach and its concrete practice have been less investigated. Zhang S Z et al. [14] combined BIM technology with VR technology to realize the digital teaching of the heating, ventilation, and air conditioning (HVAC) course. Li L Y [15] identified BIM engineering capacity from three dimensions, namely, basic ability, core ability, and development ability based on BIM-related literature, recruitment information analysis, and industrial expert interviews. You Y G [16] proposed, from the angle of market demands, that students should have BIM modeling ability, BIM application ability, and BIM project organization and coordination ability. Zhang H et al. [17] integrated the intelligent construction concept into BIM practical teaching of engineering management and explored the BIM practical teaching path of the engineering management specialty given the plights faced by the practical teaching of the engineering management specialty, such as deviated positioning of professional talent cultivation and deficient informatization quality. Yu Z P et al. [18] incorporated BIM technology into the teaching system of the engineering management specialty with "BIM student engineer class" as an example.

At present, increasingly intense demands for BIM technical personnel have been observed in fields of civil engineering, traffic engineering, and construction industry. However, the deep application of BIM is faced with various obstacles, among which the shortage of BIM talents is a primary cause. In China, most colleges and universities have not formed a systematic BIM course teaching system of discipline integration, but remained in a stage of imparting the BIM concept and BIM-related design software to students in traditional classrooms, accompanied by the shortage of a systematic multispecialty integrated teaching framework. Therefore, exploring the reform of BIM technology is extremely important in aspects of classroom teaching and engineering practice ability cultivation.

In this study, the BIM-based prefabricated concrete structure deepening teaching reform and practice were investigated with prefabricated concrete structures and construction processes in a metro station as the carrier. Moreover, the task requirement system and workflow for prefabricated concrete structure deepening design were probed, and the application depth and mode of BIM technology were summarized.

3 BIM-based prefabricated concrete structure deepening teaching and practice

3.1 Deepening course construction idea under the professional certification concept of engineering education

The professional certification of engineering education, which mainly aims to confirm that graduates of engineering majors can reach industry-accepted given quality standard requirements, refers to training objectives and graduation outlet requirement-oriented qualification evaluation with "student-centered, result-oriented, and continuous improvement" as the core concept [19].

The BIM-based prefabricated concrete structure design course is established to satisfy the demands for design talents catering to the architectural industrialization in the new era. To cultivate prefabricated building deepening design talents, the outcome-based education (OBE) concept for the professional certification of engineering education should be utilized to implement the knowledge, ability, and quality cultivation related to deepening design into the course teaching process. Therefore, the construction concept for the BIM-based prefabricated concrete structure deepening design course is described as follows. The graduation requirements of the traffic engineering especially for the prefabricated building deepening design ability are set, and the courses, from which deepening design relies upon, are determined. The teaching objectives of the deepening design course are established, and the index points of graduation requirements corresponding to the curriculum objectives are clarified. In addition, the teaching content and design process are reasonably selected to ensure that curriculum objectives can be realized.

3.2 Theoretical foundation of prefabricated concrete structure deepening design course

Prefabricated concrete structure deepening design refers to the detailed design that guides construction and production after determining the construction and structural schemes, mainly aiming at precise design and convenience for fabrication and construction. Hence, deepening design should solve the following problems: structural calculation theory, prefabricated component splitting, and deepening design drawing standard.

(1) Design theory of prefabricated concrete structures
According to the Technical Regulations on Prefabricated Concrete Structures, the construction requirements of reinforcing steel bars are largely identical with those of cast-in-place structures based on the calculation hypothesis of integrated prefabricated structures. After calculating the integrated structural model, the splitting design of the main structural components is performed to form parts, such as superposed beams, prefabricated columns, and prefabricated walls. Moreover, the detailed construction drawings of prefabricated components are prepared.

(2) Layout and splitting of prefabricated concrete components
Concrete structures should be split into independent prefabricated components to realize their prefabricated construction. Therefore, the structural form adopted for prefabricated buildings should be initially determined, the prefabricated construction parts of the building are designed, and the type of prefabricated components is selected. During component layout, a standard design idea should be adopted according to the requirement for project prefabrication rate and structural stress

characteristics to reduce the types of components and the structural forms of cast-in-place nodes and optimize the construction process for prefabricated components.

(3) Determination of drawing standards for prefabricated component deepening design The content and form of prefabricated concrete component deepening design drawings depend on the design depth requirement. In general, information, such as buildings, structures, production, and construction, should be comprehensively considered, and the design depth should be higher than the traditional construction drawing design. The deepening design drawings of prefabricated components should be prepared in accordance with the concrete demands of design drawings and project construction specified in national construction standards. Therefore, the specified drawing standards should include project information, design specifications, and drawings reflecting component production, processing, and installation. Drawings include planar and elevation drawings of prefabricated components, detailed processing template drawings, and detailed bar arrangement drawings. In addition, stress check calculation is performed on related construction processes, such as transportation and installation of prefabricated components, and the design calculation specifications are provided.

3.3 Main flow of BIM-based prefabricated I-type concrete structure deepening design

Prefabricated concrete structure design is mostly expressed by 2D CAD drawings, with problems, such as low design efficiency and difficult collaborative design, causing difficultly to satisfy the requirements of prefabricated structure deepening design for high refinement, high cooperativity, and low error-tolerant rate. However, the BIM-based prefabricated concrete structure deepening design can solve the mistake, leakage, collision, and lack of traditional design during information intercommunication through the visualization, collaboration, and simulation advantages of BIM technology. It can further improve the design accuracy and provide a quality guarantee for the subsequent production and assembly construction of prefabricated concrete components. The BIM collaboration-based prefabricated concrete structure deepening design mainly includes structural modeling, prefabricated component layout, structural calculation, collision check, check calculation of construction, and preparation of construction drawings, with the concrete design process shown in Figure 1.

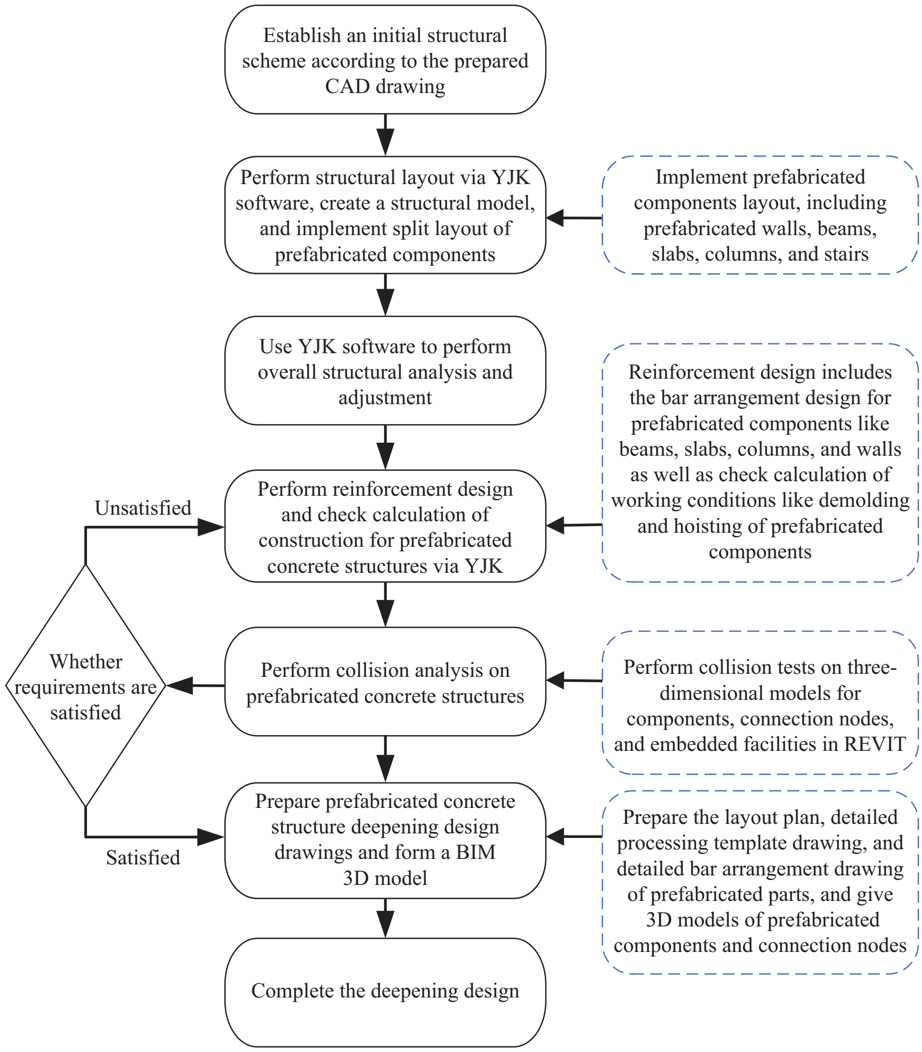

Fig. 1. BIM-based prefabricated concrete structure deepening design flow

4 Teaching case and teaching effect

With Hefei Metro Line 1 as an example, the BIM-based case teaching of prefabricated concrete structures was carried out. Hefei Metro Line 1 is the first built metro line in operation in Hefei City, with a total length of 29.06 km. The entire line is an underground line, and 23 stations are established.

4.1 Teaching objectives

The teaching objectives of this case are described as follows:

(1) Comprehend the structural calculation-related mathematical and structural mechanic principles in the software, and utilize the structural mechanics theory, through the analysis of architectural forms, to establish reasonable structural models and perform preliminary judgment of structural overall stress characteristics.
(2) Familiarize with structural design specifications, judge the definitions and effects of calculation parameters in the design software through knowledge, such as concrete structure design, predict the influences of parameter changes on the calculation result, select and optimize schemes, perform reasonable modeling and parameter setting for given structural types, and analyze structural stress characteristics.
(3) Completely implement modeling, load definition, parameter setting, computational analysis, and construction drawing preparation for prefabricated concrete structures in YJK software, arrange and split prefabricated components of the overall structure, and reasonably design the connection node forms of components.
(4) Utilize structural design software to prepare plane method-based construction drawings and detailed node drawings, use CAD software to prepare deepening design drawings of prefabricated components processing and installation information, and establish 3D models of prefabricated components via REVIT on this basis to display 3D visualization structures, steel bar collision check, and construction simulation.

4.2 Course teaching design

The BIM-based prefabricated concrete structure deepening design indicates combining structural design calculation with the 3D visualization, steel bar collision check, and construction simulation of BIM technology to realize prefabricated concrete component splitting and preparing detailed construction drawings and 3D visualization models via BIM software. Many types of BIM software are available at present, and those with the 3D construction modeling function can be classified as BIM software, such as REVIT and 3DSMAX. For this course, the BIM-based prefabricated concrete structure deepening design was studied by means of REVIT+YJK.

The prefabricated concrete structure deepening design course highlights the cultivation of students' design ability and the docking with practical engineering during teaching. With actual projects as the carrier, students are asked to practice what they have learned, and their deepening design ability is cultivated according to engineering standards. A three-stage (guidance of real-scene cases, practical operation based on division of project work, and drawing cross-review) course teaching model is established based on curriculum objectives and starting from knowledge, ability, and quality requirements.

The "three-stage teaching approach" refers to dividing the teaching process of prefabricated building structure design software application course into three stages to organically connect teaching, practice, and assessment through projects, enable students to achieve learning results, and train their design ability.

In the first stage, the prefabricated concrete structure deepening design course is taught according to course teaching objectives with the prefabricated building structure in Hefei South Station of Hefei Metro Line 1 as the project support. The station of Hefei South Station is a prefabricated concrete frame structure consisting of prefabricated slabs, beams, columns, and exterior wall panels. Through the complete structural design teaching of this project, students are enabled to master the design content and design flow of the prefabricated concrete structure as well as the auxiliary effect and application method of 3D modeling software REVIT in prefabricated component deepening design. The modeling flow of REVIT is as follows: (1) start REVIT and click "axis net"; (2) draw the axis net in the plotting area; (3) click "wall" and draw the wall body; (4) click "wall" and add doors and windows; (5) click "3D view" on the menu bar at the top; (6) click "visual form" and then "ray tracing"; (7) switch the visual pattern of the system, and check whether the modeling effect is satisfactory. The local model is shown in Figure 2. In this stage, students are also required to visit the building structure (Figure 3) in a prefabricated building plant, during which they can observe the models of prefabricated components and strengthen the intuitive understanding of prefabricated components.

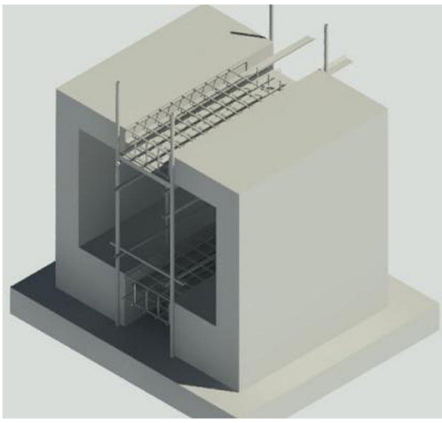

Fig. 2. Established local model

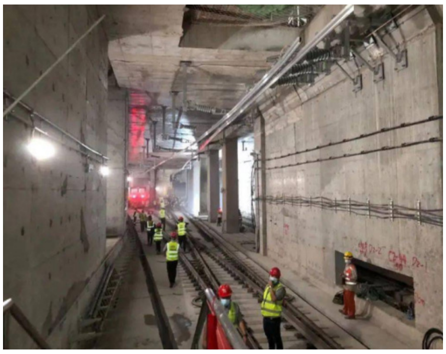

Fig. 3. Students are organized to observe prefabricated building components

After entering the second stage, students are asked to perform practical operations of the prefabricated concrete structure design project by combining the station—a prefabricated concrete frame structure—of Hefei South Station. Then, the prefabricated concrete structure modeling is implemented via YJK software, and the prefabricated components are subjected to split layout. Subsequently, loads are applied and calculation parameters are set, followed by computational analysis through the global analysis method of cast-in-place structures to obtain their bar arrangement drawing and prepare that of the prefabricated components. REVIT functions by realizing the 3D feature of the detailed bar arrangement drawings of prefabricated components and nodes as well as embedded facilities, as shown in Figure 4.

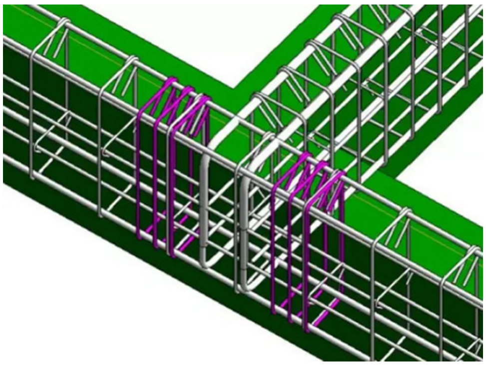

Fig. 4. Reinforcement of prefabricated components

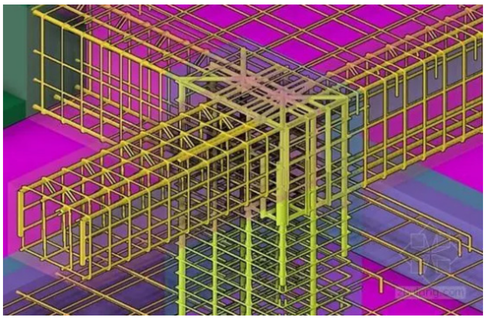

Fig. 5. 3D reinforcement model of prefabricated concrete structures

Whether steel bar layout is reasonable and whether it conflicts with other professional embedding operations can be conveniently checked through 3D display to optimize the components and node design. An overall 3D structural reinforcement model is established via REVIT software to perform steel bar collision check of different prefabricated components at connection nodes and timely solve the possible steel bar collision problem during construction, as shown in Figure 5. The installation and construction of prefabricated components are rehearsed and simulated via REVIT to discover the possible conflicts and mistakes during construction in advance and optimize the construction scheme.

In this stage, four to six students are organized into one design group and share the work of structural modeling, structural calculation (Figure 6), construction drawing preparation, and prefabricated component deepening design. They should jointly complete a set of prefabricated concrete structure deepening design drawings, including plane construction drawings and 3D prefabricated component model graphs. The teacher will assist the students and answer their questions in the classroom during group design. In this stage, the students' design ability can be cultivated based on curriculum objectives.

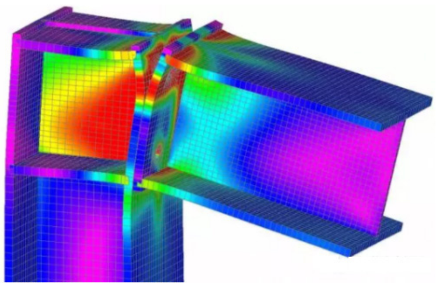

Fig. 6. Load calculation of prefabricated structures

In the third stage, after completion of the set of prefabricated concrete structure deepening design drawings with a specified time limit, drawing cross-review is performed to cultivate students' problem analysis ability. The drawing review system in actual engineering projects is simulated to carry out a collective drawing review in the classroom, during which the design group reports their design results; other groups and teacher reviewers raise questions, and the design group performs modifications and improvements according to review opinions. The teacher provides the performance score according to the quality of design results and the review results, serving as one of the evaluation indexes for the achievement of curriculum objectives.

In the three-stage teaching approach, the first stage highlights knowledge imparting, the second stage highlights design ability training, and the third stage highlights the cultivation of problem analysis ability and teamwork spirit. Practice results show that the three-stage teaching approach comprehensively trains students' deepening design ability from aspects of knowledge imparting to ability and quality cultivation. It also effectively supports the realization of curriculum objectives. The teaching process carries out the OBE concept for the professional certification of engineering education.

4.3 Teaching effect

The traffic engineering specialty in our university has started the BIM-based prefabricated concrete structure deepening teaching reform and practice since 2020. Prior to this approach, students were cultivated through the traditional teaching model. Since 2020, the new teaching model has been initially adopted and continuously improved.

To verify the teaching effect of the BIM-based prefabricated concrete structure course, after the course teaching and assessment were completed among the 2020 and

2021 students of the traffic engineering specialty, the graduation design and employer satisfaction were subsequently investigated in the form of electronic questionnaires, including students' enthusiasm for course learning, satisfaction with the teaching approach, passing rate of course examination, good rate of graduation thesis, employment rate, and employer satisfaction. The investigation results among 2019–2021 students majoring in traffic engineering are displayed in Figure 7. The students from the 2019 Class did not experience the BIM-based prefabricated concrete structure teaching reform, whereas the students from the Class of 2020–2021 participated in the BIM-based prefabricated concrete structure deepening teaching reform and practice.

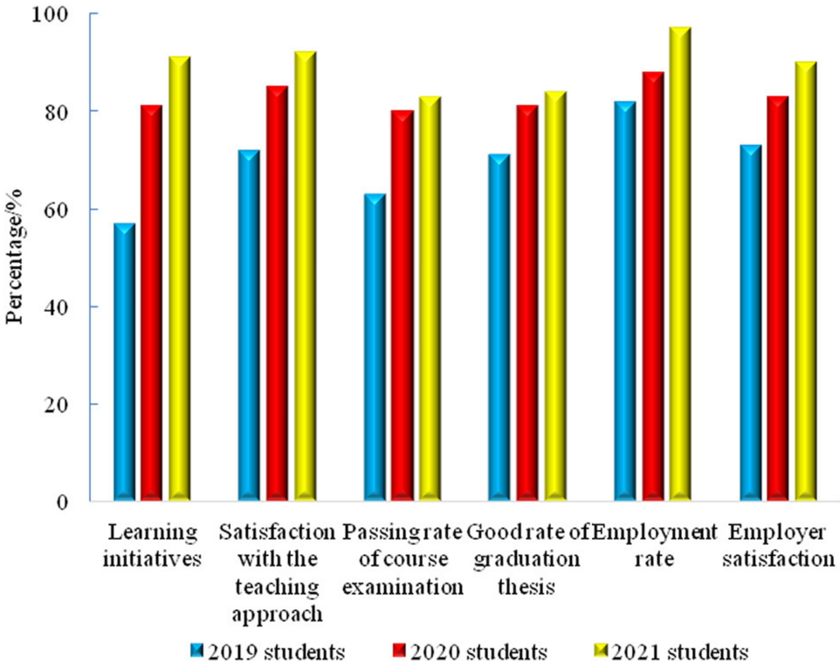

Fig. 7. Investigation results

Figure 7 shows that prior to the BIM-based prefabricated concrete structure deepening teaching reform, the learning initiatives, satisfaction with the teaching approach, passing rate of course examination, and other aspects of 2019 students failed to reach favorable results. The 2020–2021 students carried out BIM-based prefabricated concrete structure deepening teaching reform and practice, and their questionnaire indexes were higher than those of 2019 students. The learning initiatives of 2020–2021 students were greatly improved, with high satisfaction with the teaching approach. The satisfaction rate of 2021 students was 92%, and their passing rate in course examinations and good rate of graduation thesis were considerably improved, especially in the design part of graduation theses. The students completed the design content excellently via REVIT modeling software and BIM technology. Moreover, their initiative for solving the problems in prefabricated concrete structures through BIM technology was significantly enhanced, as well as their operational ability and problem-solving ability.

As revealed by the employment rate of graduates and employer satisfaction, the BIM-based prefabricated concrete structure teaching integrated processes, such as computer simulation modeling, assembly, and load computational analysis, to realize the reform of the traditional teaching model. The approach cultivated students' abilities to utilize the learned professional knowledge, simulation software, such as BIM, and solved engineering abilities. Therefore, students could basically satisfy the requirements of employers for graduates of the traffic engineering major and be recognized by employers.

5 Conclusions

The comparison of the traditional teaching model and the improved teaching model indicates that the BIM-based prefabricated concrete structure deepening teaching model can solve the deficiencies existing in the traditional teaching approach, such as concrete structural modeling, assembly, and load analysis. As a result, the teaching quality is improved, specifically manifested as follows:

(1) When the BIM-based prefabricated concrete structure deepening teaching reform and practice are carried out, students' learning initiatives are improved, and they can fully integrate the professional knowledge they learn with modern information technologies and solve concrete problems in traffic engineering through modern technologies.
(2) In the prefabricated concrete structure deepening teaching reform and practice, a teaching model integrating professional knowledge, BIM technology, and OBE is formed. This approach can improve students' understanding of prefabricated building design and construction knowledge effectively and enhance their prefabricated building construction and management abilities.
(3) To realize the course teaching objectives, a three-stage (guidance of real-scene cases, practical operation based on division of project work, and drawing cross-review) course teaching approach is proposed, and the teaching process assessment is strengthened, thereby cultivating students' prefabricated building deepening design ability effectively.

6 Acknowledgment

This study was supported by the second batch of New Engineering Research and Practice Project of Ministry of Education (E-KYDZCH20201813), Provincial Project of Anhui Province (gxgwfx2020030, 13220504, 2019jxtd048, 2018jyssf014, 2019jyxm1213, 2019jyxm1221, 2019xfxm42, 2018zygc006, 2022jyjxggyj248), National Natural Science Foundation of China (52174103, 51974007).

7 References

[1] Zhang, X. P., Li, H. T. (2019). Exploration of practical teaching construction based on prefabricated building talent cultivation. Education and Teaching Forum, (14): 164–165. https://doi:CNKI:SUN:JYJU.0.2019-14-074

[2] He, W. (2018). Exploration and research on talent cultivation of the prefabricated building direction. Journal of Jiangxi Vocational and Technical College of Electricity, 31 (5): 55-56+59. http://dx.chinadoi.cn/10.3969/j.issn.1673-0097.2018.05.025

[3] Liu, Y. L., Ding, K. W., Ma, W. (2018). Civil engineering specialty reform and practice facing prefabricated building technology. Journal of West Anhui University, 34 (3): 15–19+40.

[4] Xu, S. C., Su, Y., Cai, J. (2020). Exploration of prefabricated building talent cultivation problems in local colleges and universities under the background of production-teaching integration. Higher Education Forum, (7): 33–36.

[5] Han, F. Y., Lin, S. F. (2018). Exploration and enlightenment of the BIM professional teaching system of Purdue University in the United States. Construction Science and Technology, (22): 90–94. http://dx.chinadoi.cn/10.16116/j.cnki.jskj.2018.22.018

[6] Ali, K. N., Mustaffa, N. E., Keat, Q. J. (2016). Building information modelling educational framework for quantity surveying students: the Malaysian perspective. Journal of Information Technology in Construction, 21 (9): 140–151.

[7] Leite, F. (2016). Project-based learning in a building information modeling for construction management course. Journal of Information Technology in Construction, (21): 164–176.

[8] Espinoza, V. P. R., Cardenas-Salas, D., Cabrera, A., Coronel, L. (2021). Virtual reality and BIM methodology as teaching- learning improvement tools for sanitary engineering courses. International Journal of Emerging Technologies in Learning, 16 (6): 20–39. https://doi.org/10.3991/ijet.v16i06.13535

[9] Brok, B. S., Cadez, I. (2017). Academic teaching of BIM-development-status quo-demand for action. Bautechnik, 94 (12): 851–856. https://doi.org/10.1002/bate.201700100

[10] Shang, C. J., Li, Y. R., Ren, S. J. (2015). Innovation research of theory course and practice teaching system for construction management specialty based on BIM. Construction Economy, 36 (9): 129–132. http://dx.chinadoi.cn/10.14181/j.cnki.1002-851x.201509129

[11] Zhang, J. X., Li, H., Zhai, Y. (2016). BIM education course construction and integration analysis of engineering management specialty. Journal of Engineering Management, 30 (3): 153–158. http://dx.chinadoi.cn/10.13991/j.cnki.jem.2016.03.027

[12] Li, Q., Wang, X. F. (2016). Research on BIM-based multi-course combined teaching of civil engineering specialty in independent colleges and universities. Journal of Architectural Education in Institutions of Higher Learning, 25 (6): 85–90. http://dx.chinadoi.cn/10.11835/j.issn.1005-2909.2016.06.018

[13] Zhang, J. X., Zhao, C. D., Li, H. (2020). BIM-based multi-specialty graduation design teaching framework and empirical research from the perspective of discipline integration. Research in Higher Education of Engineering, (3): 68–73.

[14] Zhang, S. Z., Zhang, L. Z., Zhao, Y. (2019). Discussion about the application of BIM technology in HVAC teaching. Research in Higher Education of Engineering, (S1): 130–132.

[15] Li, L. Y., Li, C. Y. (2019). Study of BIM studio ability standard establishment based on the grounded theory. Construction Economy, 40 (3): 105–109. http://dx.chinadoi.cn/10.14181/j.cnki.1002-851x.201903105

[16] You, Y. G., Fu, X., Li, Q. (2018). Development status and reforming thought of BIM education in application-oriented undergraduate colleges. Journal of Information Technology in Civil Engineering and Architecture, 10 (2): 68–71. http://dx.chinadoi.cn/10.16670/j.cnki.cn11-5823/tu.2018.02.14

[17] Zhang, H., Zheng, B. Y., Tang, G. L. (2021). BIM practice teaching of engineering management specialty facing intelligent construction. Research in Higher Education of Engineering, (03): 54–60.
[18] Yu, Z. P., Gu, X. L., Cui, J. J. (2021). Exploration and practice of BIM-based "2+1+4" teaching model of the engineering management specialty. Journal of Shaoxing University (Humanities and Social Sciences (Education Edition), 41 (02): 78–83. http://dx.chinadoi.cn/10.3969/j.issn.1673-3878.2022.03.005
[19] Xie, N., Liu, J. (2020). Civil Engineering Construction Technology course reform under engineering education accreditation. Real Estate World, (19): 144–146.

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Article submitted 2022-12-05. Resubmitted 2023-01-12. Final acceptance 2023-01-12. Final version published as submitted by the authors.