Journal of Contemporary Educational Research, 2024, Volume 8, Issue 6
http://ojs.bbwpublisher.com/index.php/JCER
ISSN Online: 2208-8474
ISSN Print: 2208-8466

Application Strategies of Modular Design in Assembled Teaching Buildings

Huina Li*

Zibo Vocational Institute, Zibo 255314, Shandong Province, China

***Corresponding author:** Huina Li, 83073219@qq.com

Abstract: As an efficient, environmentally friendly, energy-saving construction method, assembled buildings are now widely used in campus building construction. Modular design thinking is system-based design thinking, and its application to the design of an assembled teaching building project will comprehensively improve the rationality of the teaching building and component design. The paper focuses on the application of modular design thinking in assembled teaching building design, aiming to provide references for China's architectural design units, giving full play to the advantages of modular design thinking in future teaching building design projects, and enhancing the level of design, for the construction of the teaching building and the basis of the technical guarantee.

Keywords: Modular design; Assembled teaching building; Basic module division; Structured parameter design

Online publication: July 3, 2024

1. Introduction

Applying modular design ideas to the design of assembled teaching building, designers can pre-formulate standardized modular components, which can be reused to reduce the cost of design, production, and construction, while further simplifying the workload of analysis of the building structure model and components, and reducing the repetitive work in the design process [1]. In addition, the modular design, when the assembled building components are constructed, can achieve the controllability of accuracy. Workers can carry out the assembly in a plant, and by assembling the components in the assembly plant, errors and accidents affecting the quality of the components can be avoided in the on-site construction process, and the repetitive use of the characteristics of the building can effectively reduce the generation of construction waste, and improve the environmental protection of the construction of the teaching building.

2. Overview of modular design ideas

The application of modular thinking in construction is an innovative design and construction method. The idea breaks down the building into prefabricated and pre-assembled modules (also called "modules"), which will be precisely produced in the factory according to the design drawings and subsequently assembled on-site. Combined with a large number of modular design building experiences in the past, it can be concluded that the modular design thinking of construction engineering, its design process, and results have the following characteristics: first is system-based design thinking. Modular thinking, with emphasis on the whole and part of the association, requires full consideration of the design of the modules and the coordination between different modules early in the design stage [2]. The second characteristic is repeatability and standardization. The difference between modular thinking and traditional customized building design is that it pursues the reuse of module design and standardized design, which can effectively reduce costs and improve efficiency. The third characteristic is integrated construction. Modular thinking believes that the construction of buildings is not only a matter of on-site construction but also includes the design of prefabricated components, transport, on-site installation, and other aspects. This way of thinking motivates the architectural designers to develop integrated solutions to organically integrate all the links together, and then improve the overall construction project [3].

3. Characteristics of assembled teaching building project engineering

3.1. High accuracy requirements

In the assembled teaching building project, the accuracy of the components needs to be strictly controlled in the construction and production stage, and in order to meet the design requirements, the precision requirements of prefabricated parts of the assembly are very high [4]. In the construction of the teaching building project, the laboratory, classroom, library, and other functional areas of the size, installation location, interrelationships, etc. need to be strictly controlled to meet the requirements of the use, which puts forward higher requirements for the rationality and accuracy of the project design.

3.2. Short construction cycle

Assembled design can greatly compress the construction cycle because it allows production in the factory and construction site installation at the same time. For teaching building projects, the construction cycle is often limited due to the start of the school year, summer and winter holidays, etc. The application of assembled building technology aims to effectively solve the problem of short construction periods.

3.3. Diversification of construction

Although the assembled design pursues factory and standardization, the variety of prefabricated modules and their combination can effectively solve the requirement of diversified building forms and structures. Especially for the teaching building project, compared with residential, the teaching building has more functional areas, so we need to diversify the design ideas to meet the different functional areas of the reasonable design and collocation, and meet the needs of the later teaching function of the building [5].

4. Application of modular design in assembled teaching building

4.1. Basic module division

4.1.1. Basic functional module design

In the assembled teaching building, the primary task of applying modular design ideas is to divide the basic functional modules according to the actual needs of the teaching building, and then design each functional module in sequence to meet the specific functional needs of future education work. For the assembled teaching building, the basic functional modules can be divided into classrooms, offices, public service areas, laboratories, and gymnasiums.

(1) Classroom module: The classroom is the main place for school teaching activities and should have a good teaching environment and facilities. During the modular design, the designer needs to standardize the spatial layout and facility configuration of the classroom module to effectively improve the audio-visual effect of the teacher-student group in the future applicable stage and promote communication and interaction [6].

(2) Office module: The office is the core space for the daily work and academic activities of faculty and staff, and its design needs to provide good comfort, adequate storage space, and the necessary communication equipment. The modular design should be flexibly adapted to different work needs to improve the efficiency and effectiveness of space allocation.

(3) Public service area module: The public service areas in the teaching building are concentrated in the washrooms, stairs, lifts, and corridors. During the modular design of public services, it is necessary to meet the high degree of functionality and convenience, such as the need to facilitate pedestrian flow, provide effective guidance, etc., modular design, aims at providing standardized solutions for these utilities to meet the traffic, safety, health, and other multi-dimensional requirements.

(4) Laboratory module: Laboratory design needs to consider the characteristics of the experimental equipment, laboratory personnel safety, and the convenience of the experimental process. The modular design aims to plan a comfortable, flexible, and efficient space for the laboratory and quickly create a specialized laboratory environment for the school.

(5) Gymnasium module: As an important part of the campus, the design stage of the gymnasium needs to consider the planning of the venue, equipment selection, and the creation of a sports atmosphere and environment. During the modular design, the design is mainly aimed at the size of the venue and the suitability of sports [7].

4.1.2. Core cylinder module design

In the core cylinder design stage, first of all, the designer needs to determine the location of the core cylinder according to the functional and structural layouts of the building. At the same time, in order to make the building structure more stable, the core cylinder should be set near the geometric center or gravity center of the building. Usually, during the design of the teaching building, the aspect ratio of the core cylinder module should be set to 3:1 or 6:1 to ensure its stability. For concrete strength, in order to ensure the structural stability of the teaching building and the service life of the building, the concrete grade of the prefabricated components should usually be ≥ C30. The design of the evacuation channel width must comply with the requirements of the building code to ensure that the group of students and teachers can be quickly evacuated in case of emergency. At the same time, the vertical traffic design should take into account the number and size of lifts to meet the demand for use during the peak hours of commuting to and from school. In terms of the piping arrangement, the piping of each system in the core cylinder should be neatly concentrated and orderly arranged, and the power and communication lines should be designed with enough reserved space [8].

4.1.3. Supporting module design

In the design stage of the assembled teaching building, the modular design idea is not only applicable to the main functional area but also to the design of supporting modules. These supporting modules, usually include balconies, roof waterproofing works, lift rooms, and HVAC (heating, ventilation, and air conditioning) works. The application of modular design ideas in these supporting facilities can effectively improve construction efficiency and reduce maintenance costs.

For one thing, in assembly buildings, the design of balcony modules needs to consider functionality and aesthetics. In general, the width of the balcony should be designed between 1.5 and 2.5 m, and the length can be set according to the actual needs of the building to ensure its functionality and comfort. The balcony railing height is usually set to 1.1 m, in order to ensure the security of teachers and students in the school. Secondly, during the design of the roof waterproofing module, the prefabricated waterproofing board is an effective and widely used solution for the assembly of school buildings, and the thickness of the waterproofing board should be set at 3–4 mm to ensure that good waterproofing functions are brought into full play on the basis of not increasing the weight too much. Thirdly, the design stage of the lift module includes the supporting lift shaft, machine room, and control room. The lift shaft size design needs to give full consideration to the lift load and scale, usually, the lift shaft length x width shall not be less than 1.5 x 1.5 m, and the lift shaft interior should maintain air circulation. Fourthly, the HVAC engineering module design includes the main design of air conditioning units, ducts, and control systems. The size of the air conditioning unit should be set according to the scale of the teaching building and the temperature control demand, and the diameter of the air duct should be designed according to the air supply volume of the HVAC system.

4.1.4. Standard floor plan combination design

The application of standard floor plan combination design in modular design ideas of assembled teaching building is mainly reflected in the unit module, around the core cylinder module of the diversified combination of changes, such as repetition, symmetry, rotation, etc., to meet the needs of different areas and functions.

On the one hand, the basic unit module of the classroom needs to meet certain specifications. In general, the length and width of the classroom unit module can be set to 6–12 m to ensure that it can meet the scale of 30 to 60 people, but also to facilitate the production and handling of the module. On the other hand, different layouts of the standard floor plan can be realized by combining the unit modules in a repetitive, symmetrical, and rotational manner. For example, two relatively symmetrical classroom modules can be designed to form a large classroom with a capacity of 120 people, and multiple classroom modules can be arranged vertically to form a teaching corridor that integrates multiple small classrooms.

4.1.5. Modular design of structural components

The application of structural components design in the modular design idea of the assembled teaching building is mainly reflected in the unitized, standardized design to achieve a combination of construction, the goal is to further enhance the efficiency of the assembly construction method and to reduce the cost of quality assurance at the same time.

The main structural components of the assembled teaching building module focus on beams, columns, plates, and connecting components. During the design of beams, columns, and plates, certain standard dimensions need to be met in order to simplify the production and combination of modules. For example, the thickness of the plate should be set at 150 mm to 300 mm, and the length of the unit module should be set at 6 m to 12 m to ensure that the construction can fully meet the requirements of classrooms of different scales and functional areas. Connection components as a part of the connection between modules, common modular connection components include bolt connection, precast concrete connection, plug connection, etc. In the connection components design stage, designers need to fully consider the ease of operation and the stability of the later application, for example, the length of the common bolt connection can be designed for 20 mm to 40 mm, and the diameter is designed for 10 mm to 20 mm.

4.1.6. Facade combination module design

Facade combination module design, that is, through adjusting and combining different facade modules to achieve the enrichment and diversification of the appearance of the building and maintain the quality of the project and the construction period requirements according to the building use function and external environment requirements.

Facade combination module design mainly includes windows, doors, walls, and other decorative elements. These modules can be mass-produced in the factory and assembled on-site through standardized and serialized design. During the design period, the window modules can be designed according to different sizes and shapes, and combined according to specific needs to meet the lighting and ventilation needs of the interior of the teaching building. For the wall modules, different materials and colors can be used to achieve an aesthetically pleasing visual effect on the facade. In addition, by adjusting the combination of modules, the appearance of the building can also achieve certain energy-saving and environmental protection effects, such as setting the sunshade can effectively block solar radiation and reduce the air-conditioning operating load.

4.2. Structural design

4.2.1. Structural layout design

Structural layout design is to design the modules of different prefabricated components of the assembled teaching building. Module design of prefabricated component structures emphasizes modular scale design. As an important design unit, the module represents a certain size and is the core content of prefabricated component design and layout. Modular design thinking needs to be used to give full play to its characteristics of flexibility and replaceability [9]. During the design period, the size, shape, joint type, etc. of prefabricated components can all be standardized based on modular design. During the design period, designers should make reasonable length, width, and height adjustments for prefabricated components such as columns, wall panels, beams, etc. Modular design and planning ensure that each structural component can be spliced together accurately, reducing measurement and trimming time during construction.

4.2.2. Structural parameter design

Structural parameter design is to design the specific parameters and proportion information of prefabricated components based on the structural layout design based on the modular idea. During the design period, the dimensions of prefabricated components of different specifications and models were mainly considered in order to meet functional requirements while improving the convenience of later construction [10]. **Table 1** shows the design information of prefabricated component parameters and proportions for a school's assembled teaching building.

Table 1. Prefabricated component parameters and proportion design of a school's assembled teaching building

Classification of prefabricated components	Quantity	Specification	Percentage
Prefabricated shear walls	45	t = 200 (1800m)	15.8%
	120	t = 200 (3100m)	42.1%
	120	t = 200 (2500m)	42.1%
Stacked panels	68	1270 x 3700	6.06%
	136	1000 x 2000	12.12%
	170	2520 x 3100	15.15%
	204	2500 x 3720	18.18%
	204	1420 x 2500	18.18%
	272	1675 x 3120	24.24%

Table 1 (Continued)

Classification of prefabricated components	Quantity	Specification	Percentage
Prefabricated stairs	34	1200 x 2080	100%
Prefabricated laminated beams	68	200 x 600 (4.1 m)	18.18%
	68	200 x 600 (3.7 m)	18.18%
	68	200 x 600 (2.7 m)	18.18%
	136	200 x 700 (7.0 m)	36.36%

5. Conclusion

In summary, the modular design idea applied in the design of the assembled teaching building is mainly reflected in the basic function module design and structured parameter design, in which the basic function module contains the basic function module design, core cylinder module design, supporting module design, standard layer plan combination design, etc. In light of this paper for the rational application of modular thinking, the design unit should also try to design with information technology, such as the establishment of a three-dimensional model based on BIM, so as to enhance the design accuracy, predict the design effect in advance while providing effective guidance for the development of subsequent construction programs. The modular design can further enhance the value of the application of modular design ideas to meet the design requirements of the assembled teaching building and the later use of functional requirements.

Disclosure statement

The author declares no conflict of interest.

References

[1] Zhang SH, Hu JF, An ZL, et al., 2022, Modular-Based Design of Assembled Structure. Outdoor Equipment, 2022(4): 271–273.

[2] Liu B, Liu L, 2023, Application of BIM-Based Modular Assembly Plant Room Technology in Hunan Creative Design Headquarters Building Project. Installation, 2023(3): 28–30.

[3] Jie J, Hu H, 2023, Research on Modular Design of New Assembled Composite Wall Structure Residential House—Taking Shaanxi Area as an Example. Building Energy Saving, 51(2): 19–24, 46.

[4] Wang X, Yan W, Zhang Z, et al., 2023, Design of Modular Assembled Steel Structure Stereo Garage. Science and Technology Innovation and Application, 13(33): 41–44.

[5] Han X, 2023, Research on Modular Design of Assembled Steel Structure Residence Based on BIM Technology. Brick and Tile World, 2023(17): 22–24.

[6] Li C, Zheng Y, 2023, Research on the Design of Assembly Highway Service Area Based on Modularisation—Taking Jixiang Service Area as an Example. Chongqing Architecture, 22(6): 33–36.

[7] Fan J, Zhang X, Cheng C, 2023, Research Progress of Modular Design Method Based on Assembly Building. China Building Metal Structure, 22(10): 99–101.

[8] Yan B, 2023, Research on Structural Design of Modular Assembled Buildings. Brick and Tile, 2023(12): 83–85.

[9] Liu MY, 2024, Research on the Optimisation of Green Building Assembly Modular Design and Construction Process. Real Estate Guide, 2024(1): 127–129.

[10] Wang X, Yan G, Liu W, et al., 2023, Design and Finite Element Analysis of HGIS Modular Assembled Concrete Cellular Foundation. Journal of Wuhan University of Technology, 45(7): 89–94.