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A Practice in China for Computer Aided Design and Construction of Prefabricated Enclosure Walls

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Abstract: This article combines the author's past software development and other work practices related to computer-aided design and construction of building enclosure walls, discussing how computer technology can assist in various methods and directions during the design and construction of building enclosure walls. It mainly involves structural design of load-bearing enclosure walls, structural design of non-load-bearing enclosure walls, thermal insulation design of building enclosure walls, waterproof design of building enclosure walls, planning for enclosure wall hoisting, calculation verification for enclosure wall hoisting, and construction of enclosure walls. Whether in the design of the main structure of the building or in the planning and decoration of the building space, designers need to put in a lot of effort for enclosure walls. It is worth studying how to fully utilize the capabilities of computer technology to free up more time for designers. This article has certain reference value for research and application in related fields.

Key words: enclosure walls, CAD, CAE, BIM, architectural design, structural engineering, interior design

1. Introduction

The building enclosure walls is an important component of the building system (not necessarily part of the main structural system), playing a pivotal role in building structure and architectural space design. Generally speaking, building enclosure walls can be constructed as brick walls, concrete walls, stone walls, timber walls, glass curtain walls, metal walls, etc. as well as inorganic material walls (such as glass fiber-reinforced inorganic materials). Based on their load-bearing characteristics, the enclosure walls of a building can be categorized into load-bearing walls and non-load-bearing walls.

However, there are pain points and problems to be solved for traditional enclosure wall design and construction process. The poor fire resistance, insufficient waterproof and anti-seepage, moisture-proof performance, lousy insulation effect, and low strength are flaws. And the construction process is complex and time-consuming, which increases construction costs and time. The development of prefabricated buildings and Construction Industrialization [1] can solve many problems. Meanwhile prefabricated engineering design and construction process bring new issues that need attention.

For example, prefabricated components require strict dimensional planning, and prefabricated components with incorrect dimensions will become waste; The demand for multi-disciplinary collaborative design is more evident, and precise hole reservation is required; There are added requirements for short-term working condition verification of individual components, such as lifting, delamination, etc.; The number of drawings has greatly increased, and non-structural professional information is also required to be supplemented in the drawings; The problem of data silos in design is becoming increasingly prominent, and the demand for integrated design, production, and construction data is becoming stronger. So new

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engineering design and construction process requires new computer-aided technology. There is no much systematic and targeted research to this series of multi-disciplinary issues targeted towards prefabricated walls.

The article discusses the trying of one computer software scheme that integrates prefabricated component design and traditional structural engineering design into one big process, called "YJK's built-in prefabricated building design software", which may adapt to the need to support the prefabricated walls design and construction processes of selection, planning, and installation. Involving several targeted aspects, such as structural design, insulation design, waterproof design, and installation engineering of prefabricated enclosure walls.

2. CAD for Prefabricated Load-Bearing Enclosure Walls

2.1 Technical Scheme

Believe in the law that if the solution process is clear, rule-based expert systems or similar systems can be used, else if the solution process is unclear, machine learning is needed to obtain rules.

Because the design, calculation and detailing process can be planned as deterministic programs and user interactive programs in computers, so the final scheme was as two aspects, one as a rule-based systems, the other as an interaction system. All data was embedded within the structural analysis software.

In short, it was based on structural design models, rule-based, and integrated into the main process of structural analysis.

2.2 Wall Type

Currently, in the practice of prefabricated building structures in China, the common-used prefabricated walls are based on the "Prefabricated Concrete Shear Wall Exterior Panels" (15G365-1) and "Prefabricated Concrete Shear Wall Interior Panels" (15G365-2).

In addition, more and more types of prefabricated wall systems are emerging in China, each with its own advantages. In the YJK's built-in prefabricated building design software, besides supporting the above two kinds of wall of manuals, it also supports various forms such as single-row sleeve prefabricated walls, double-row full-sleeve prefabricated walls, double-sided composite shear walls (widely used in Germany), and vertically unconnected prefabricated walls, etc.

2.3 Design Process

In the YJK's built-in prefabricated building design software, the general design process of prefabricated walls includes: establishing structural models, designing prefabricated wall subdivision schemes, performing overall structural calculations, editing reinforcement in a planar view, carrying out detailed design of prefabricated walls, making detailed drawings of prefabricated walls, and exporting the inventory list table of prefabricated walls.

According to the current design logic of YJK's built-in prefabricated building design software, the prefabricated wall subdivision scheme is a specialized task based on the existing building structure model. Of course, with the rapid development and maturity of the national building industrialization level, the software may gradually evolve into another systematic workflow following the progress of the industry, and on the other hand, optimization algorithms for subdivision scheme design should be introduced [2]. Fig. 1 shows the subdivision scheme for prefabricated wall in the software (dark coloured filling parts are prefabricated walls).

Based on current practice and understanding, in the proposed amendments to the "Technical Standard for Sawtooth-Shaped Prefabricated Concrete Shear Wall Structures" (T/HNKCSJ011-2024), it is suggested that the original provision 3.0.1, which reads "Design of prefabricated subdivision scheme, including structural selection, structural layout, force transfer path, and production and assembly of prefabricated units of structural components", be revised to read: "Overall scheme design, including structural selection, structural layout, design of prefabricated subdivision scheme, force transfer path, and production and assembly of prefabricated units of structural components." This is because, based on the reading and understanding of this standard, provision 3.0.1 mentions a total of five structural design processes of the building's structural system. It is believed that the first process does not solely encompass the "design of prefabricated subdivision scheme".

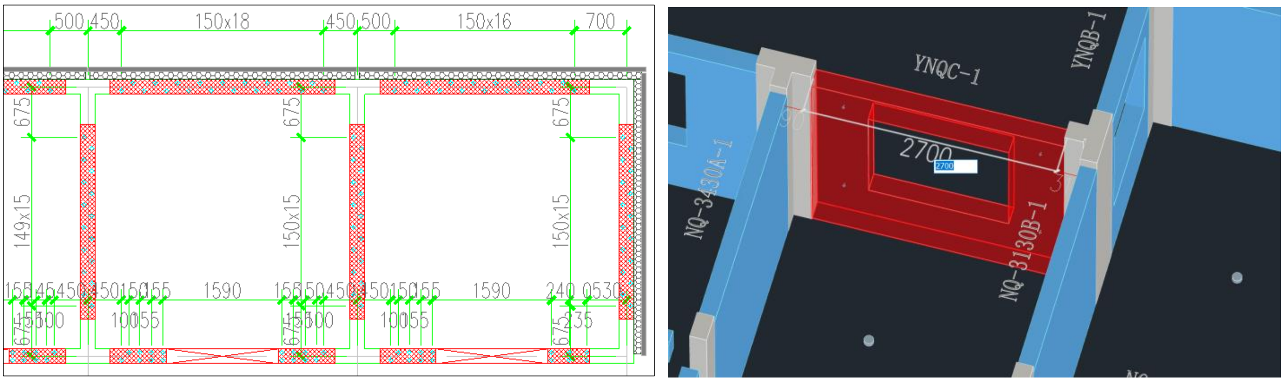


Fig. 1 Subdivision scheme for prefabricated walls of 15G365-1 manual and 15G365-2 manual in YJK's built-in prefabricated building design software.

2.4 Calculation

In the integrated prefabricated shear wall structure system, other than overall calculations (Fig. 2), node connections performance is also important. the Technical Specification for Prefabricated Concrete Structures (JGJ1-2014) stipulates that the shear bearing capacity of the horizontal joints at the bottom of prefabricated shear walls should be checked.

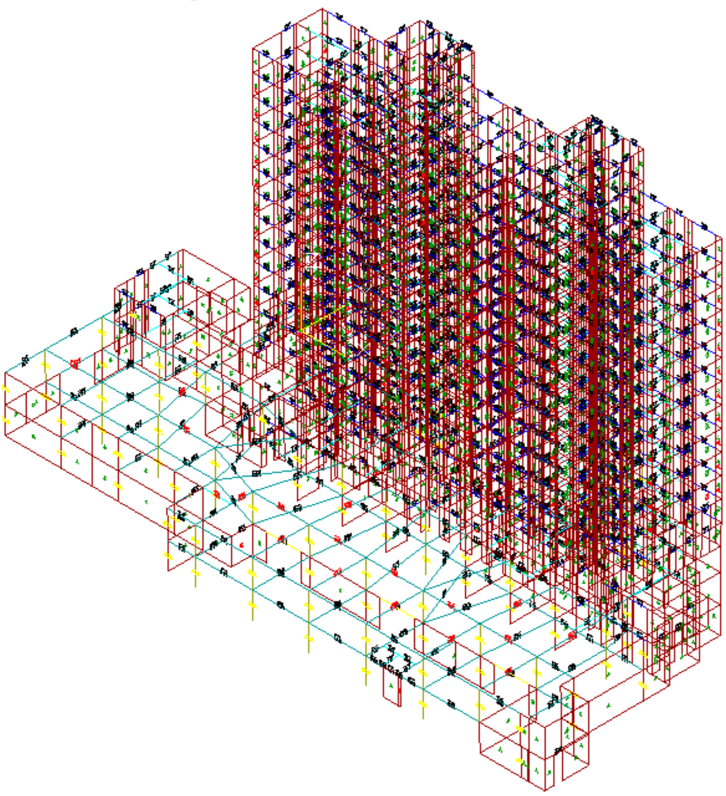


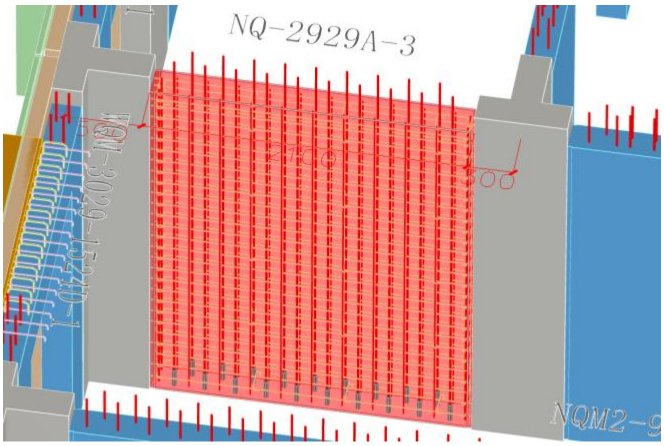
Fig. 2 Shear wall building model for structural calculation.

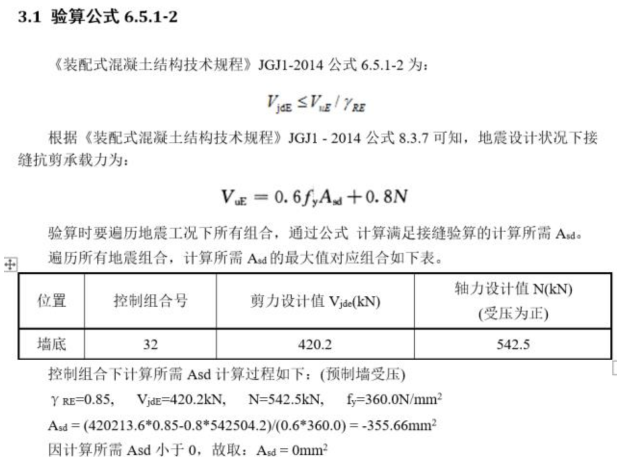
In the YJK's built-in prefabricated building design software, there are corresponding functions (Fig. 3).

2.5 Component Reinforcement and Detailed Drawings

In the YJK's built-in prefabricated building design software, the principle of "normal construction drawing first" is followed. The design process involves the normal construction drawing by Ichnographic Representing Method and the detailed reinforcement drawing for prefabricated walls. Presently, for the detailing of prefabricated components, we have designed special interactive dialogs, in fact, different usage environments require different BIM model accuracy [3]. The process of obtaining detailed reinforcement for prefabricated walls is shown in the Fig. 4 (the left is the normal construction drawing by Ichnographic Representing Method, the right is the detailed reinforcement drawing for prefabricated walls).

After obtaining detailed reinforcement information, you can proceed to review the reinforcement diagram (inventory list table) for prefabricated walls.





3.1 验算公式 6.5.1-2

《装配式混凝土结构技术规程》JGJ1-2014 公式 6.5.1-2 为：

$$V_{jdE} \le V_{uE} / \gamma_{RE}$$

根据《装配式混凝土结构技术规程》JGJ1 - 2014 公式 8.3.7 可知，地震设计状况下接缝抗剪承载力为：

$$V_{uE} = 0.6 f_y A_{sd} + 0.8N$$

验算时要遍历地震工况下所有组合，通过公式 计算满足接缝验算的计算所需 A_{sd}。遍历所有地震组合，计算所需 A_{sd} 的最大值对应组合如下表。

位置	控制组合号	剪力设计值 V_{jde}(kN)	轴力设计值 N(kN) (受压为正)
墙底	32	420.2	542.5

控制组合下计算所需 Asd 计算过程如下：(预制墙受压)

γ_{RE}=0.85, V_{jdE}=420.2kN, N=542.5kN, f_y=360.0N/mm^2

A_{sd} = (420213.6*0.85-0.8*542504.2)/(0.6*360.0) = -355.66mm^2

因计算所需 Asd 小于 0，故取：A_{sd} = 0mm^2

Fig. 3 Some result content of the prefabricated wall horizontal joints calculation in YJK's built-in prefabricated building design software.

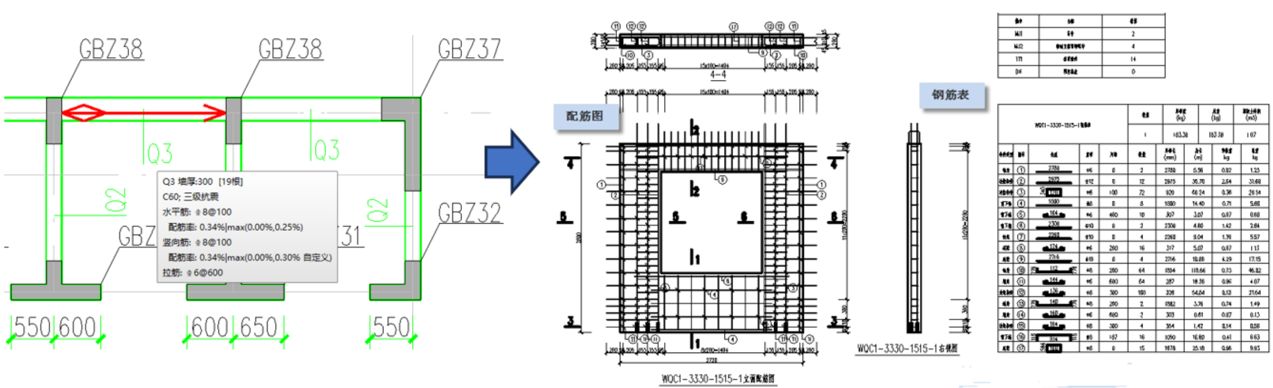


Fig. 4 Prefabricated wall reinforcement obtaining process in YJK's built-in prefabricated building design software.

3. CAD for Prefabricated Non-Load-Bearing Enclosure Walls

3.1 Technical Scheme

Generally speaking, non-load-bearing walls are not parts of structural analysis model. Because current structural analysis only focuses on the load and rough stiffness contributions it causes, without the strong need for precise non-load-bearing wall model data. But some experts do strongly suggest accurately stiffness considering.

Actually in YJK structural software, non-load-bearing walls can be modelled. Simultaneously, prefabricated non-load-bearing walls can be modelled based on the ordinary non-load-bearing wall data.

In short, prefabricated non-load-bearing walls was based on ordinary non-load-bearing wall data in the structural design software, and is rule-based, and integrated into the main process of structural analysis.

3.2 Wall Type of Ordinary Non-Load-Bearing Wall

Non-load-bearing enclosure walls can be categorized based on their stress characteristics as self-supporting walls and partition walls.

And partition walls are classified according to their construction methods as follows:

(1) Block Partition Wall

Block partition walls are constructed by block units made of some kind of material such as ordinary bricks, hollow bricks, aerated concrete, etc. The degree of prefabrication is relatively low, and nowadays they are less commonly used in prefabricated buildings than before.

(2) Lightweight Frame Partition Wall [4]

The lightweight frame partition wall consists of two parts: the frame and the surface panel layer. The frame can be made of wood or metal, and the surface panel layer can be made of wood, plywood, fiberboard, gypsum board, etc.

(3) Plate Partition Wall [4]

Plate partition wall refers to the direct installation of lightweight plates with relatively large dimensions in length and width (generally as the size of one floor height or one room width). The lightweight plates can be made of autoclaved lightweight concrete strip panels (ALC, wall assembled by slats), composite slab walls, etc. It is easy to assemble and is widely used in prefabricated buildings nowadays.

In special, for frame structure buildings, non-load-bearing enclosure walls can be categorized into infilled walls and curtain walls. And the infilled walls (including internal partition walls and external partition walls) can be prefabricated.

3.3 Prefabricated Concrete Non-Load-Bearing Enclosure Wall

Regarding the scale of approximately one floor height, the prefabricated concrete non-load-bearing enclosure wall can be either a single piece of wall or an wall assembled by slats.

For the kind of single piece, the YJK's built-in prefabricated building design software can support various types of prefabricated concrete non-load-bearing walls such as prefabricated infilled walls, prefabricated beams with partition walls, and prefabricated external wall panels.

For the kind of wall assembled by slats, software can support prefabricated walls assembled by strip panel slats made of ALC (autoclaved lightweight concrete).

The design and selection of External Enclosure Walls has a direct impact on the façade of the building and should be considered holistically [5].

3.4 Design Process

The design process of prefabricated non-load-bearing enclosure walls in YJK's built-in prefabricated building design software are: establishing a structural model with non-load-bearing walls, specifying prefabricated non-load-bearing walls, checking and calculating prefabricated non-load-bearing walls, editing the detail of prefabricated non-load-bearing walls, making detailed drawings of prefabricated non-load-bearing walls, and exporting the inventory list table of prefabricated non-load-bearing walls.

The screenshot shown in the figure depicts a portion of the designated and editable features for prefabricated non-load-bearing walls in YJK's built-in prefabricated building design software.

3.5 Computer-Aided Calculation Related to Structural Safety

The bearing capacity of the external enclosure wall should be calculated under the effects of wind load and seismic load.

In the YJK's built-in prefabricated building design software, the action effect of the prefabricated external enclosure wall refers to 10.2 of the Technical Specification for Prefabricated Concrete Structures (JGJ1-2014). The calculation is carried out separately for the two cases of "upper end fixed and lower end hinged", as well as "upper and lower end hinged", and the envelope is taken. The bending bearing capacity of the wall body is checked with reference to 6.2.10-1 of the Code for Design of Concrete Structures (GB 50010-2010) and the Technical Specification for Prefabricated Concrete Structures (JGJ1-2014). The shear bearing capacity of the wall body is checked with reference to 6.3.1-1, 6.3.3-1, 6.3.3-2 of the Code for Design of Concrete Structures (GB 50010-2010) and the Technical Specification for Prefabricated Concrete Structures (JGJ1-2014). The node bearing capacity is checked separately for in-plane shear and out-of-plane tensile resistance. The figure shows part of the results.

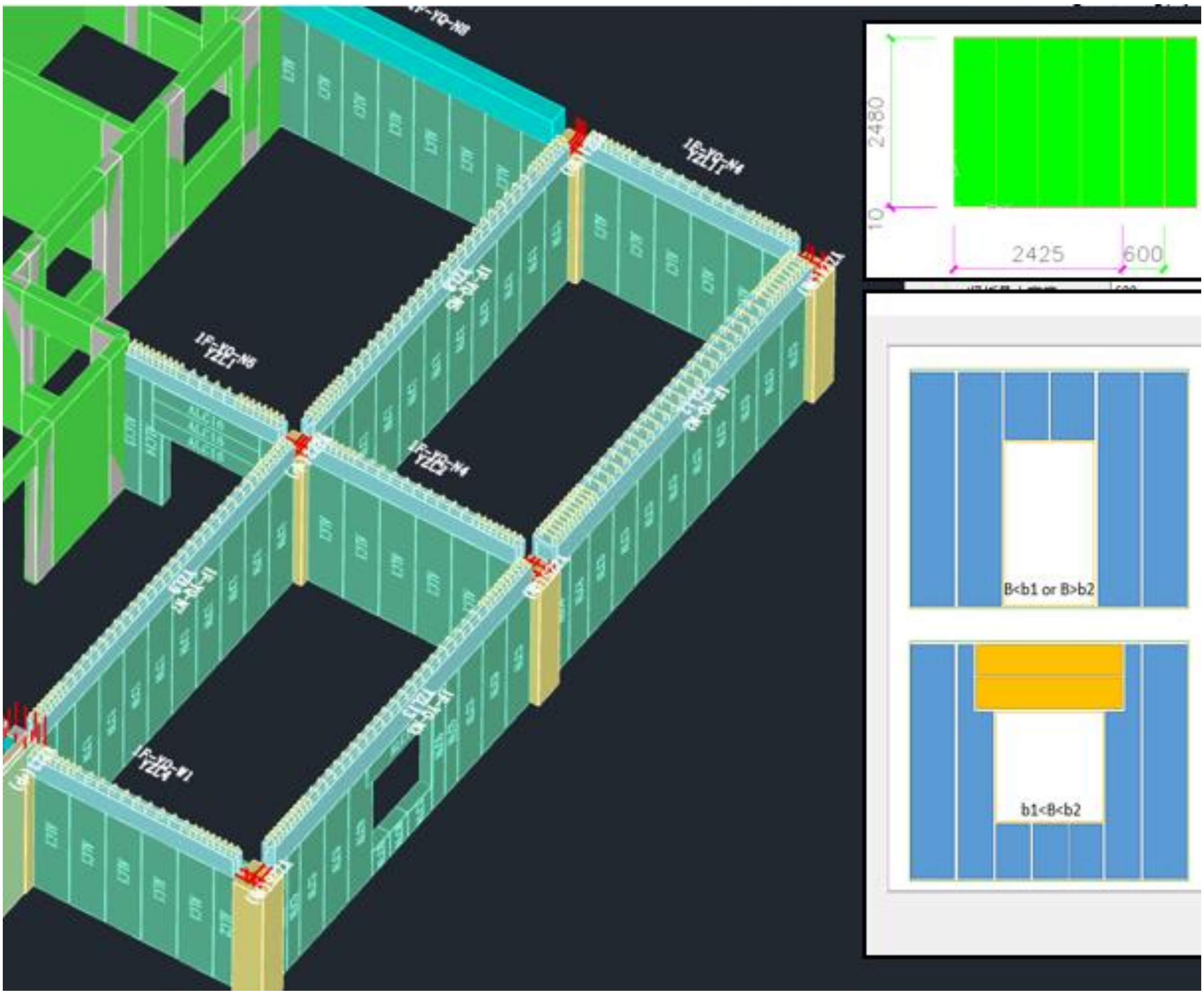


Fig. 5 The designation and subdivision functions for prefabricated non-load-bearing walls (ALC, assembled with slats) in YJK's built-in prefabricated building design software.

4. The Enclosure Wall in the Automatic Assembly Rate Calculation

4.1 Technical Scheme

Assembly rate is currently a reference indicator in China for evaluating the industrialization level of prefabricated buildings. This indicator roughly represents the proportional between prefabricated and non- prefabricated parts. In fact, the calculation methods vary greatly, and there are different calculation regulations in different regions of China.

Fig. 6 Some part of calculation for prefabricated external non-load-baring enclosure wall in YJK's built-in prefabricated building design software.

The calculation process is not completely clear even according to specific regulation. But it is not very suitable for using machine learning methods because to some extent the answer to question is like a contractual relationship and the rules are still in development and discussion. So the software system was planned as rule-based expert system, permitting different regions switching to different rules.

4.2 Software Implementation

The screenshot shown in the Fig. 8 depicts the UI of load-bearing and non-load-bearing enclosure walls when automatically calculating the assembly rate in YJK's built-in prefabricated building design software, based on the national standard "Evaluation Standard for Prefabricated Buildings" (BG/T51129-2017). Additionally, it supports over twenty other local calculation regulations for different regions.

5. Thermal Insulation Design and CAD Technology for Prefabricated External Enclosure Walls

5.1 Technical Scheme

Heat preservation in winter and thermal insulation in summer are crucial considerations that cannot be overlooked in external enclosure wall architectural design.

This issue is solely about the prefabricated enclosure wall itself, and have nothing to do with the underlying structural design or structural models.

Current technical solution categorizes this issue as a deepening design of components. For example, the placement of insulation layers for walls of different types and shapes, the definition method of local insulation components, etc..

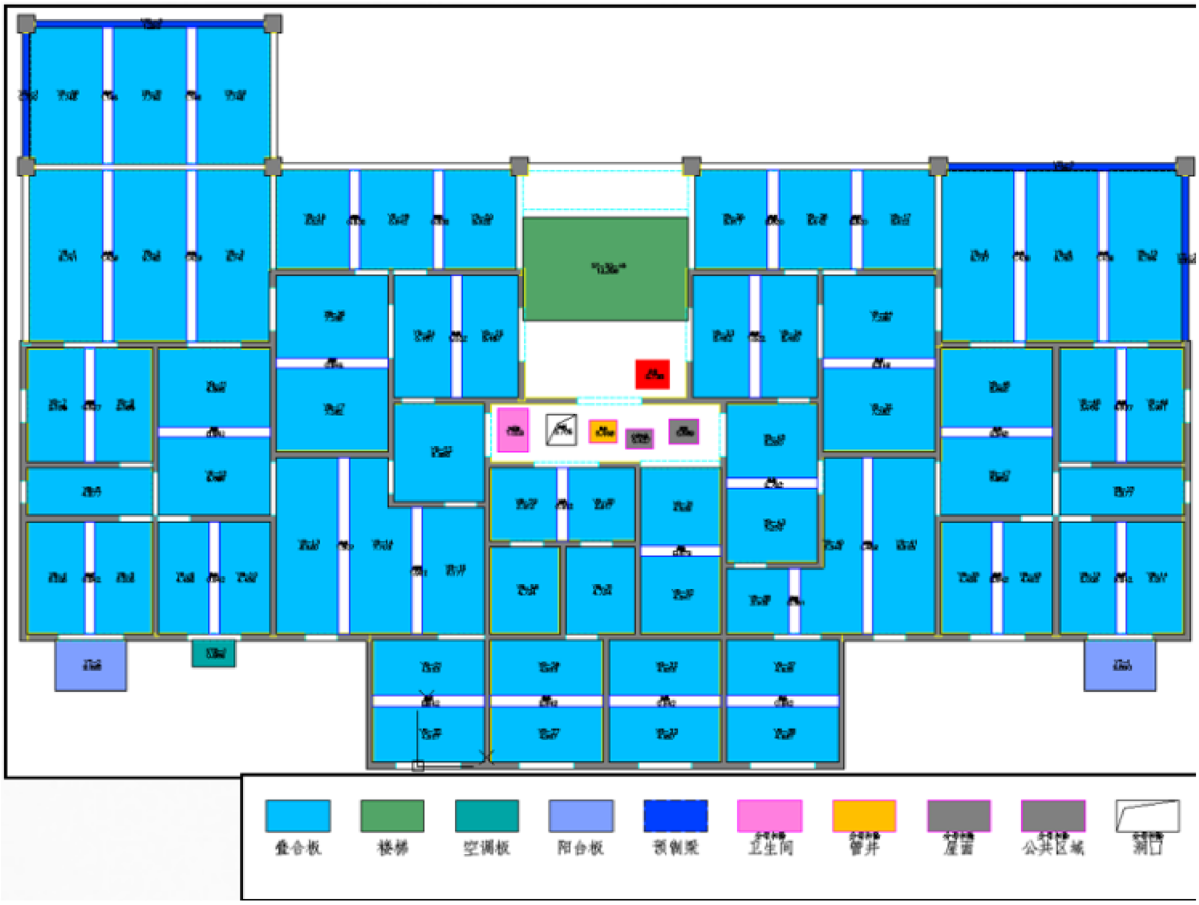


Fig. 7 The assembly rate calculation view in YJK' s built-in prefabricated building design software.

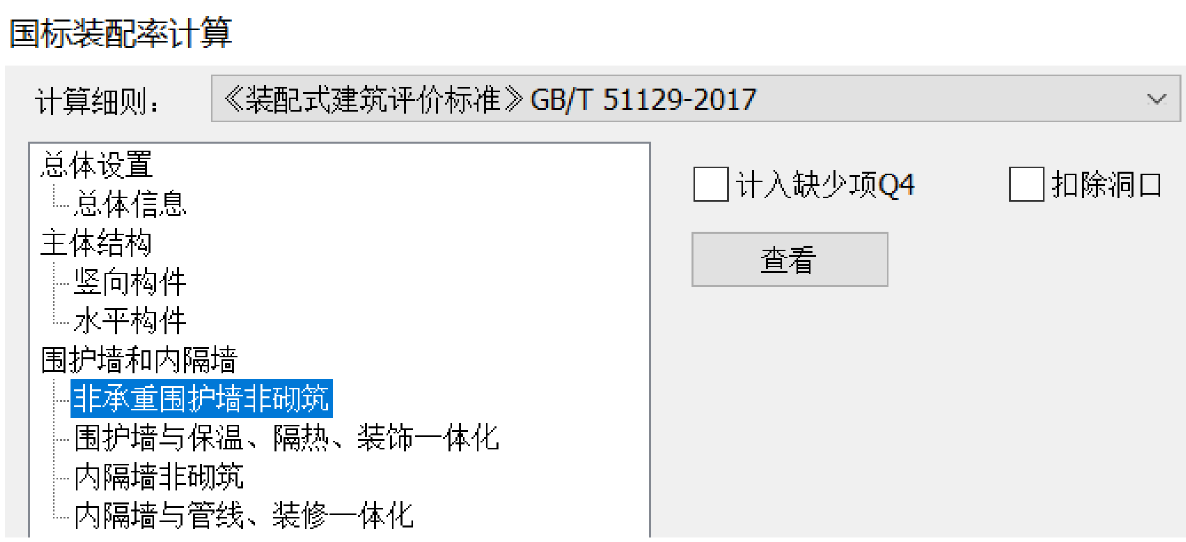


Fig. 8 Part of the UI related to non-load-bearing enclosure walls in the calculation of assembly rate using YJK' s built-in prefabricated building design software (for national standard).

5.2 Heat Preservation and Thermal Insulation Design for Different Kind of Wall

In YJK's built-in prefabricated building design software, the types of insulation supported include: sandwich prefabricated external walls with insulation layer (national standard load-bearing prefabricated walls, Fig. 9), double-sided laminated walls (including load-bearing walls and non-load-bearing walls) with internal insulation layers, and embedding boards.

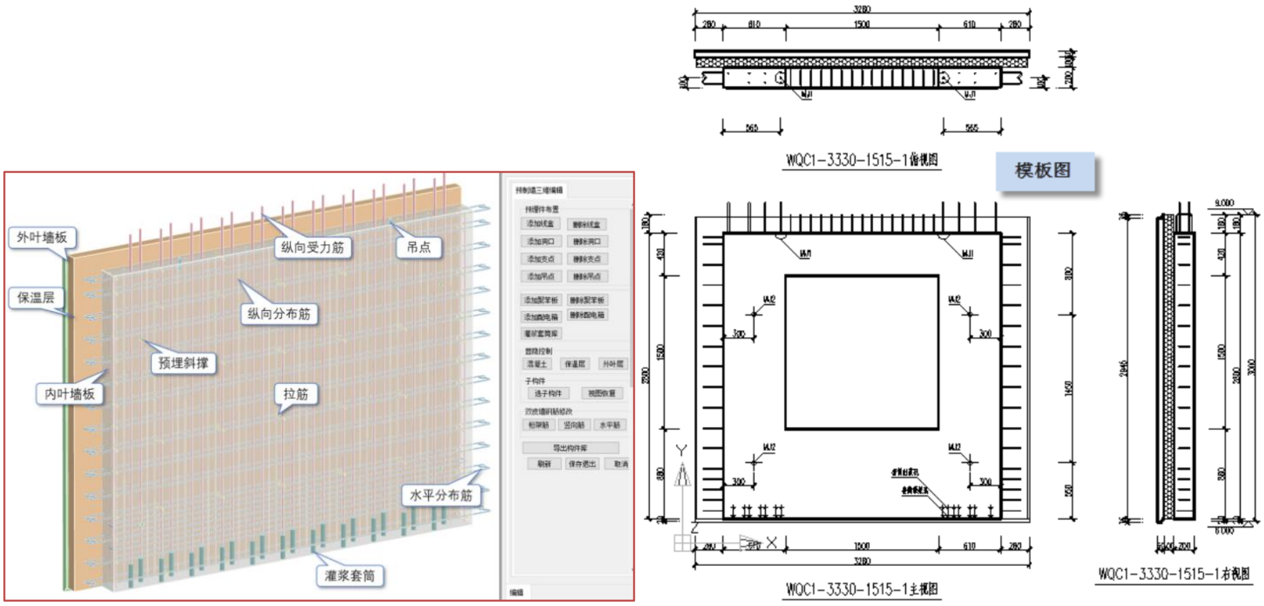


Fig. 9 A sandwich prefabricated external wall (with an insulation layer which is larger than wall itself) in YJK's built-in prefabricated building design software (for national standard).

5.3 Insulation Material

The insulation layer material for the external enclosure wall can be spray-on insulation materials such as polyurethane insulation materials; insulation boards made from inorganic fiber materials, such as glass wool and rock wool; and insulation boards made from polystyrene resin, including expanded polystyrene (EPS) boards and extruded polystyrene (XPS) boards.

YJK's built-in prefabricated building design software supports embedding polystyrene boards for prefabricated walls to reduce self-weight (weight-reducing boards), at the same time, it can guarantee insulation functionality. On the other hand, the material of insulation layer for sandwich prefabricated external walls is not yet clearly defined in software.

5.4 Fire Protection for Insulation Layer

The "Technical Specification for Prefabricated Concrete Structures" (JGJ1-2014) 4.3.2 stipulates that the combustion performance of insulation materials in sandwich external wall panels should meet the requirements of Class B_2 in the "Classification for Burning Behavior of Building Materials and Products" (GB8624-2012). According to Chapter 4 of the "Classification for Burning Behavior of Building Materials and Products" (GB8624-2012), Class B3 refers to flammable materials.

To comply with the Technical Specification for Prefabricated Concrete Structures, according to the provisions of JGJ1-2014, the amendment suggestion for the "Technical Standard for Sawtooth-Shaped Prefabricated Concrete Shear Wall Structures" (T/HNKCSJ011-2024) is to adjust the original provision "The insulation layer should be made of materials with a combustion performance not lower than Class B. The thickness should be determined by calculation" to "The insulation layer should be made of materials with a combustion performance not lower than Class B_2. The thickness should be determined by calculation".

The fire protection standards for the insulation layer of the external enclosure wall should be improved in accordance with regulations, in order to prevent the spread of fire from one part of the building to another along the external wall as much as possible.

Although YJK has the function of fire resistance calculation for structural components, the fire resistance for insulation layer is suggested to be confirmed through the definition method in the previous two sections.

6. Waterproof Design and CAD Technology for Prefabricated External Enclosure Walls

6.1 Technical Scheme

Waterproof performance is another important design consideration for the external enclosure walls.

This issue is solely about the prefabricated enclosure wall itself, and have nothing to do with the underlying structural design or structural models.

Current technical solution also categorizes this issue as a deepening design of components. For example, waterproof details of vertical connection nodes for prefabricated wall outer leaf panels, and treatment for horizontal connection nodes between prefabricated walls.

6.2 Waterproof Material

In article 4.3.1-2 of the Technical Specification for Prefabricated Concrete Structures, it is stipulated that silicone, polyurethane, and polysulfide building sealants should comply with the provisions of Silicone Building Sealants (GB/T14683), Polyurethane Building Sealants (JC/T482), and Polysulfide Building Sealants (JC/T483), respectively.

The Technical Specification for Prefabricated Concrete Structures (JGJ1-2014) does not specify any restrictions on the use of sealants, so proposing amendments to "Technical Standard for Sawtooth-Shaped Prefabricated Concrete Shear Wall Structures" (T/HNKCSJ011-2024) that it is recommended to lift the restrictions on the use of sealants. Specifically, the original provision "The joints of the external protective layer should be sealed with structural sealants. The durability and performance indicators of the structural sealants should meet the relevant provisions of the current national standard 'Silicone Structural Sealants for Building' GB16776" is suggested to be adjusted to "The joints of the external protective layer should be sealed with structural sealants. The durability and performance indicators of the structural sealants should comply with the relevant provisions of the current national standard".

If there are no other considerations, designers should be able to independently weigh and select the appropriate sealant based on project needs.

6.3 Design Related to Waterproof

The YJK's built-in prefabricated building design software has been enhanced with the ability to automatically set tongue-and-groove joints, following the criterion method of the national standard for prefabricated external shear walls as shown in the Fig. 10.

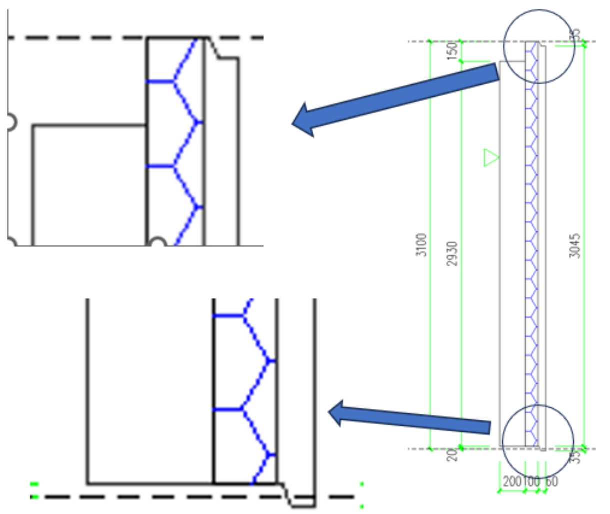


Fig. 10 YJK's built-in prefabricated building design software automatically sets up tongue-and-groove joints for prefabricated external walls.

People also can use YJK's built-in prefabricated building design software to design horizontal nodes of the external enclosure walls mutually, as shown in Fig. 11.

At present, the details exist as geometric information, and related technologies about BIM semantic information should be further studied[6].

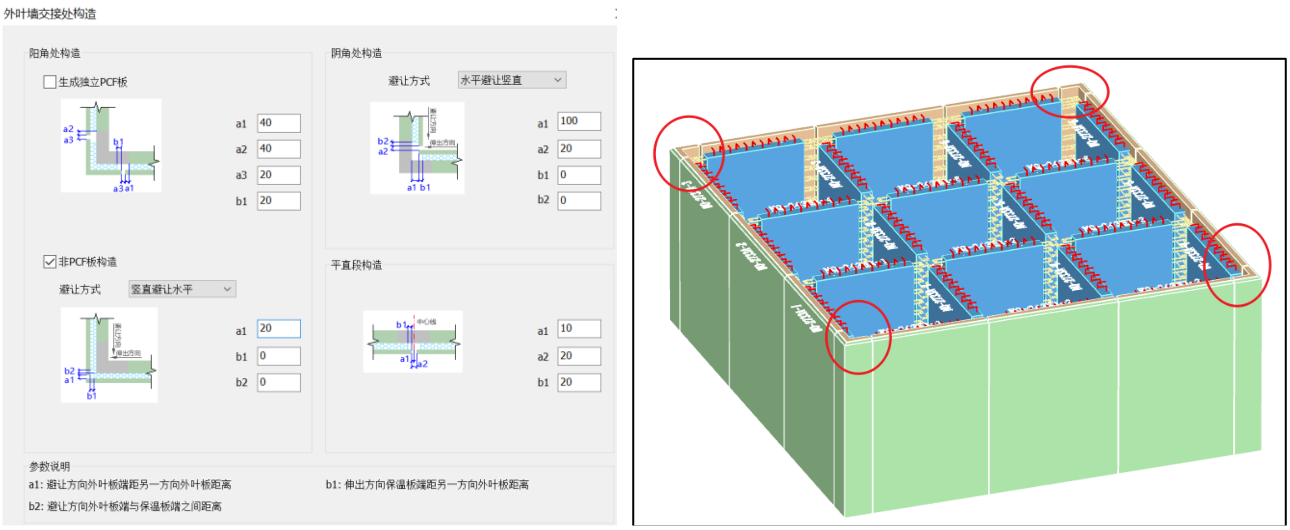


Fig. 11 Wall horizontal connection node design in YJK's built-in prefabricated building design software.

7. Computer Technology for the Construction of Prefabricated Enclosure Walls

7.1 Technical Scheme

Regarding construction, if we focus on the issue of prefabricated components, it can be assumed that this issue is solely about prefabricated enclosure wall itself, and have nothing to do with the underlying structural design or structural models.

However, there are various issues with different aspects to be solved. Firstly, 3D Model based visualization is required for installation planning function, and the core technology is about Computer Graphics. Secondly, independent lifting safety calculation is needed in the lifting validation, and Material Mechanic is the core related knowledge. Thirdly, to achieve automatic installation, it is required that the design data can match the on-site environment, so the core is about data transmission and sharing, coordinate alignment between computer data and the real world. There are many other aspects that can be assisted by computer technology, such as monitoring the status of materials and components during the construction process [7].

7.2 Installation Planning

To achieve the goal of facilitating users in planning and simulating the construction installing of wall panels, efforts in two aspects were made.

The hoisting scheme function in YJK's built-in prefabricated building design software is implemented by the way of dynamic display of the different components in the model.

On the other hand, reinforcement collision is always a troublesome thing for prefabricated components. Steel collision detection program provides prompts. In some cases, also providing a certain degree of automatic avoidance solutions (Fig. 12).

7.3 Lifting Verification

Some parts of the calculation content for the hoisting calculation function in the YJK's built-in prefabricated building design software is shown in the figure below. It can automatically perform hoisting calculation verification for wall panels and output a complete hoisting calculation sheet.

7.4 For Wall Installing Robot

The key technologies for wall installing robots are perception (sensors) coordinate positioning, navigation, decision-making, etc..

The integration of wall installation robots with BIM enclosure wall data can be achieved by the alignment of virtual and real spatial coordinates. This enables accurately placing the enclosure wall to the correct position and angle at the construction site. The robots should do specific tasks such as carrying, setting out, etc.

ALC wall data of YJK's built-in prefabricated building design software can be imported into REVIT for subsequent robotic operations (Fig. 14), while other wall data can be imported into AUTOCAD for subsequent robotic operations. Specific data transmission methods include IFC [8], etc.

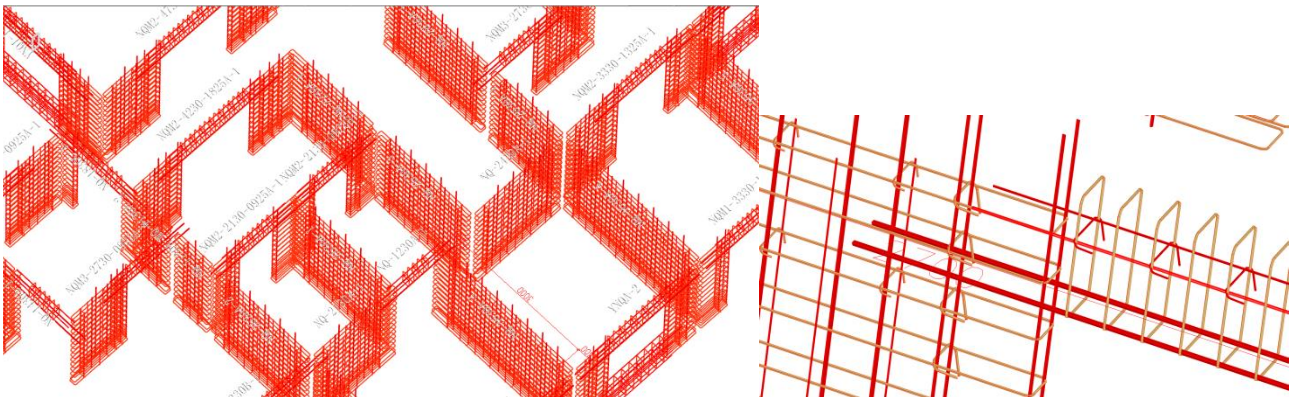
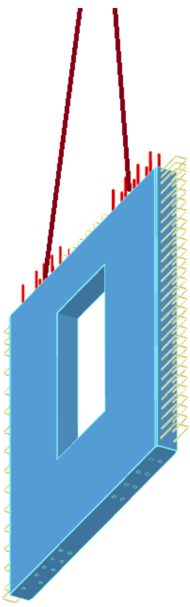


Fig. 12　Reinforcement collision detect program in YJK's built-in prefabricated building design software.



3.1 混凝土开裂验算

根据《混凝土结构工程施工规范》GB50666-2011 第 9.2.3 条：

吊点	跨长 L1(mm)	跨长 L2(mm)	跨长 L3(mm)
吊点排布	550	1650	640

取 1 米板带作为计算单元 L_0=1m

计算线荷载 $q=Q_k*L_0/S=57.51*1/7.7=7.50$kN/m

根据吊点位置，最大跨中弯矩值 $M_{MAX中}=1.22$kN · m

最大支座弯矩值 $M_{MAX支}=-1.54$kN · m

控制弯矩值 $M_{MAX}=\max(|M_{MAX中}|, |M_{MAX支}|)=1.54$kN · m

截面抵抗矩 $W=B*H^2/6=1*0.2^2/6=0.0067m^3$

正截面边缘混凝土法向拉应力计算：$\sigma_{ck}=M_{max}/W=1.54/(0.0067*1000)=0.23N/mm^2$

脱模时按构件混凝土强度达到抗拉强度标准值的 75.0%, 经验算

$\sigma_{ck}<75.0\%*f_{tk}=1.50N/mm^2$，满足要求！

3.2 脱模件承载力验算：

单个吊件脱模吊装荷载计算：

$z=1/\cos\beta=1.00$

$F_D=G*z/n=38.34*1.00/4=9.58$kN

$N_{sa1}/\gamma_1=36.00/4.00=9.00kN<9.58kN$　不满足要求！

3.3 脱模混凝土锥体破坏强度验算：

单根锚栓受拉，理想混凝土锥体破坏时的受拉承载力标准值：

Fig. 13　Some parts of the calculation content for wall hoisting in YJK's built-in prefabricated building design software.

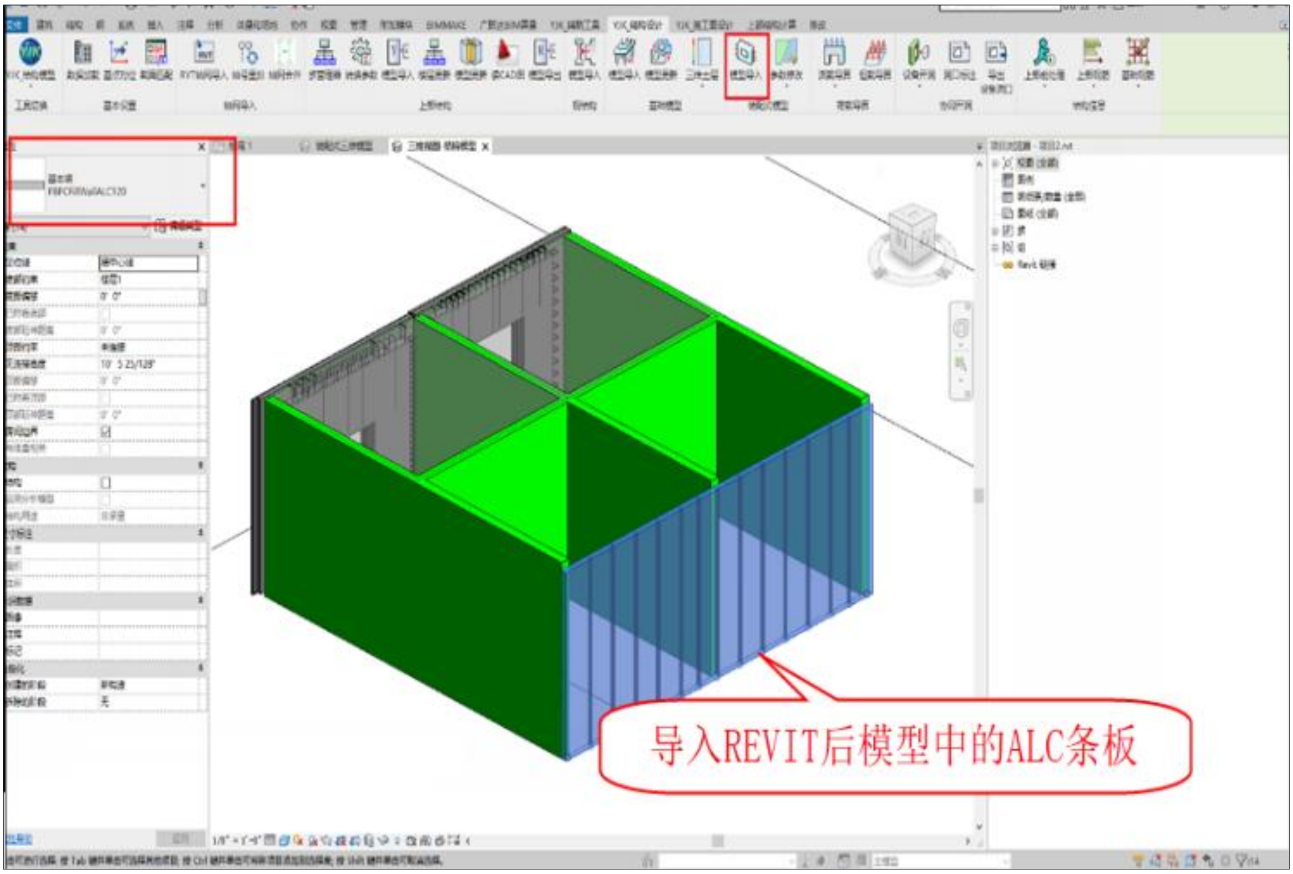


Fig. 14 Output ALC data into revit.

7.5 Roughly Estimating Carbon Emissions

The entire process of carbon emission calculation can be divided into three stages: the production stage of prefabricated components, the transportation stage of prefabricated components, and the construction stage.

Factors influencing calculation during transportation phase mainly include transportation distance, fuel consumption, etc. and issue of empty load should be considered. Currently there are also research for intelligent planning of component transportation [9]. At the construction phase, calculation results show that carbon emission of prefabricated buildings is significantly less than that of cast-in-place buildings.

Speaking of carbon emission calculation during the production phase, the accuracy depends on the precision of the steel reinforcement data, and further improvement is needed for software.

8. Summary

During the entire process of building enclosure walls, from design to installation and construction, computer-aided technology can be leveraged to enhance productivity in many areas.

This article discusses several computer technology solutions. It primarily covers the structural design of load-bearing and non-load-bearing enclosure walls, insulation design and, waterproofing design for external enclosure walls, as well as hoisting and construction. It should be noted that not all implemented content has been listed here. There are both successful experiences and lessons that need to be learned. One of the successful experiences is the benefits brought by close integration. Lessons learned include that detailed design should be based on a more powerful 3d platform, which is currently on the way to implementation. In addition, the refinement of functions is also underway, for example, targeted functional improvements and new multi-disciplinary collaboration solutions.

From the perspective of auxiliary design goals, current technological solutions mainly focus on traditional computer-aided methods based on interactive commands, which is a similar approach to expert systems. In other words, there hasn't been much involvement of computers in creative work. However, current computer technology can participate in more of the work of human engineers.

In fact, the next generation of auxiliary design solutions need to be considered. The typical problem at the first level is the editability of design specifications and the storage scheme of specifications suitable for computer automatic recognition (Knowledge Graph and other non-sql databases need to be evaluated). The typical problems at the second level are intelligent structural scheme design, intelligent planning of prefabricated building subdivision schemes, and intelligent reinforcement design based on large knowledge library (Machine Learning methods for small data need to be evaluated). For the design of individual prefabricated components in the renovation of old houses, it is timely to study more automated computer-aided methods such as automatic spatial recognition and automatic planning of component layout based on spatial data.

References

[1] Costa, S., Carvalho, M.S., Pimentel, C., & Duarte, C. (2023). *A systematic literature review and conceptual framework of construction industrialization*, *Journal of Construction Engineering and Management* 149 (2) 03122013.

[2] Gan, V. J. L. (2022). BIM-based building geometric modeling and automatic generative design for sustainable offsite construction, *Journal of Construction Engineering and Management* 148 (10) 04022111.

[3] Jang, S., & Lee, G. (2024). BIM library transplant: Bridging human expertise and artificial intelligence for customized design detailing, *Journal of Computing in Civil Engineering* 38 (2) 04024004.

[4] Fujian Provincial Department of Housing and Urban-Rural Development (2021). *Technical Standard for Prefabricated Building Envelope Wall Structure*: DBJ/T13-343-2020.

[5] Gilani, G., Pons, O., & de la Fuente, A. (2021). Sustainability-oriented approach to assist decision makers in building facade management, *Journal of Construction Engineering and Management* 148 (1) 4021182.

[6] Wang, Z., Sacks, R., Ouyang, B., Ying, H., & Borrmann, A. (2023). A framework for generic semantic enrichment of BIM models, *Journal of Computing in Civil Engineering* 38 (1) 04023038.

[7] Mengiste, E., Mannem, K. R., Prieto, S. A., & Garcia de Soto, B. (2024). Transfer-learning and texture features for recognition of the conditions of construction materials with small data sets, *Journal of Computing in Civil Engineering* 38 (1) 04023036.

[8] buildingSMART (2024). IFC4.3.2.0, available online at: https://standards.buildingsmart.org/IFC/RELEASE/IFC4_3/

[9] Jang, J. Y., Kim, J. I., Koo, C., & Kim, T. W. (2022). Automated components — Vehicle allocation planning for precast concrete projects, *Journal of Management in Engineering* 38 (6) 04022059.