great growth. In a word, construction industrialization means to construct a house as that of an automobile, thus we can apply lean philosophy and tools on construction projects more efficiently.

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BIM Application Research of Assembly Building Design: Take ALLPLAN as an Example

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ABSTRACT

Based on the application of ALLPLAN software under BIM platform, focusing on ALLPLAN outline dimension, reservation and pre-burying of rebar, and collision detection design application, analyze document data and logistics list, obtained advantages and disadvantages of ALLPLAN design platform, to provide support and further promotion of BIM platform application in prefabricated buildings.

BIM OVERVIEW

"BIM" refers to "Building Information Modeling", which is the technology, method or process for supporting the construction, operation and administration decision of project life cycle through expressing geometry, physical and functional information with digital technology (Wang 2015).

The practice of BIM is mainly popularized by Finland, Norway and Singapore initially, which is followed by America. Currently, multiple states of America already have legislation to require the necessity for adopting the BIM technology in large-scale public building project within the states, and the national BIM standards and technical committee are established at the same time for guiding the better application of overall industry and developing the BIM technology; especially in BIM application promoting to the prefabricated buildings.

With the continuously perfecting of BIM technology in Japan, the prefabricated building is applied into the high and super high-rise buildings at earthquake region based on the development and application of prefabricated building with BIM technology; and prefabricated buildings fully play the antiknock characteristic in several sudden earthquakes, and protect the life safety, thus, more extensive attentions are obtained on BIM.

Europe is the birthplace of prefabricated building, and the history may be traced back to the 17th century at the earliest, thus the cognition starting of European countries is earlier on prefabricated building. In Britain, the cost of public building project is reduced for 15%-20% by the British government through BIM technology, and the combination of BIM and green building with the amount below 5 million pounds was realized in 2016.

Since introducing the BIM technology in 2002, the advantages of combination in BIM technology and prefabricated building is increasingly obvious, with rapid development speed. Shenzhen Vanke Center is a typical application of prefabricated building based on BIM technology. Nowadays, Chinese building industries such as Vanke, Greenland, Merchants and other land agents, CSCEC, CREC and other contractors and SANY, Zoomlion and other

manufacturers begin to seek for industrial transformation so as to strive for promising in modernization of construction industry and vigorously researching and developing the BIM technology based on prefabricated building for rapid development of BIM research in domestic.

ALLPLAN DESIGN PLATFORM

BIM software "Allplan", which developed by Nemetschek (Austria) Engineering GmbH, has swept the world with widely using. All prefabricated components are divided into interior parting wall, exterior parting wall, beams of interior parting wall and exterior parting wall, interior wall and exterior wall of prefabricated shear wall, wall hanging, composite beam, prestressed composite beam, composite floor slabs, prestressed hollow slab, prestressed composite sheet, frame column, stairs, balcony, air conditioning board and bay window through analyzing common system of prefabricated building, namely, frame system (frame and frame-shear), shear wall system and wallboard system. And the design of prefabricated components is divided into three modules by Allplan design platform, namely, wall, board and irregular parts, through which the design of above prefabricated components can be met; See Figure 1 for the partial model of prefabricated components.

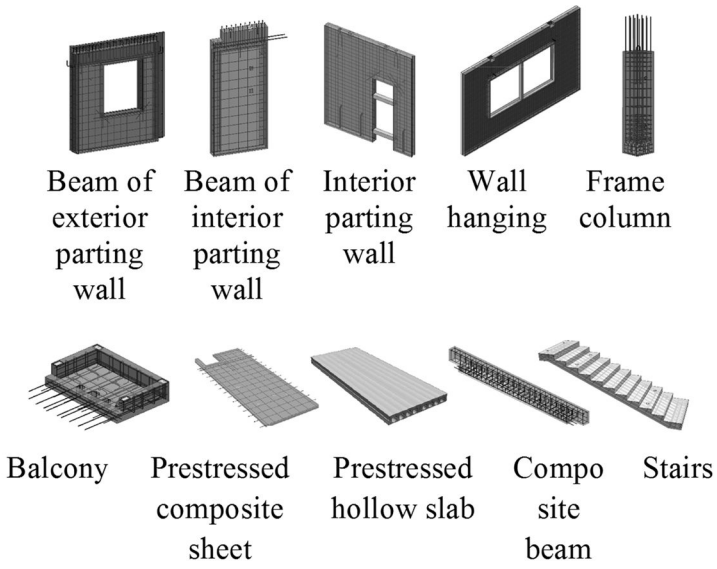

Figure 1. Model of prefabricated components.

Overall design of prefabricated parts: The wall type, material composition, joint construction around the wall and treatment at openings for doors and windows shall be confirmed at first. In Allplan, the wall type is divided into sandwich wall, concrete wall, double wall and thermal storage wall etc., and the exterior parting wall with beam (see Figure 2) can be designed as sandwich wall in Allplan. The sandwich wall has three layers: visible layer, insulating layer and invisible layer, and the layer indoor is defined as visible layer; thus, the materials and thicknesses of the wall with three layers are: concrete + XPS (200mm); EPS (50mm); concrete (50mm) respectively. Among which, the weight reduction material XPS in the visible layer is buried in the concrete as surface pre-buried parts (Gao 2015). And the material of invisible layer may be changed as exterior board, which is used as facing layer of exterior wall (Wang et al. 2014; Sun et al. 2013).

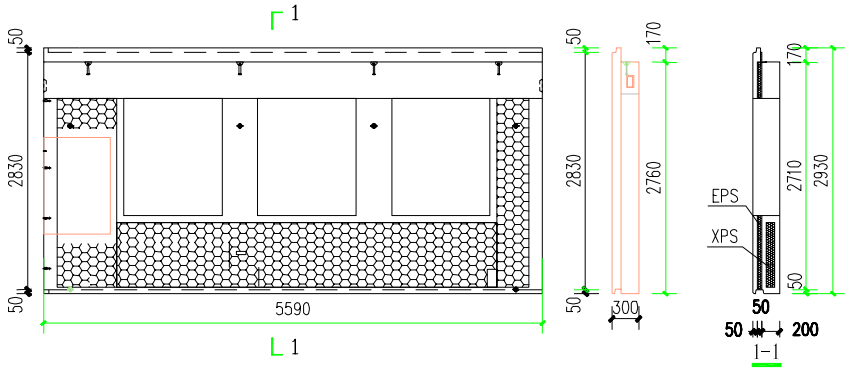

Figure 2. Dimensional drawing of exterior wall with beam.

As for the upper and lower structures of the wall, the inconformity height of visible layer, insulating layer and invisible layer is caused due to the waterproof structure and cast-in-place on the upper of wall. Allplan software has the special module for adjusting the height of layers in upper and lower of wall when prefabricating and designing the wall, through which, the inconformity can be eliminate through height customization. To ensure the strength of waterproof ridge of the upper of wall visible layer, the concrete thickness of such place is increased to 90mm from 50mm (extend 40mm to the inner of insulating layer), and the height of extension section and thickness to be extended may be customized with "concrete strip at the top and bottom". The required overall dimension of waterproof ridge at the upper wall and groove at the lower wall may be formed by removal and denomination of the modeling in the prefabrication unit.

As for the structure at both ends of wall, the insulating layer of which is sealed with concrete, and may be treated either with joint nodes of components or compiling of insulating layer. In case the joint node is adopted, the joint node of concrete sealing port may be generated at the end part of wall by selecting the definition connection type of adjacent walls (orperpend wall) and the nodes at the ends of walls are matched. There are 8 connection types in Allplan software, which may realize substantially all wall connection nodes, and for the nodes fail to be realized, customized development can be made. In case compiling of insulating layer is adopted, the part cut from the insulating layer at both ends will be filled with concrete automatically by software after cutting.

As for the windows, doors and openings, the necessity for compiling of the insulating layer should be made with overall consideration while the special waterproof structure is established. Both of them can be realized with corresponding commands in Allplan design platform.

Rebar arrangement of prefabricated parts: It is more complex as for the rebar inside the exterior parting wall with beam, thus, it will be disposed by dividing the rebar into following three categories: the first category is rebar for strengthening wall foundation, which is set with parameterization, namely, the rebar type needs by strengthening the wall foundation is set in the software at first, such as C6@200 and C4@150, then, select one layer of C6@200 rebar for visible layer and two layers of C4@150 for the invisible layer when making strengthening design for wall foundation. And the extension, retraction and lap joint type of rebar around the wall can be defined and the rebar at the doors and windows and openings can be broken.

The second category is rebar inside the beam, which can be made with a FF component (the

rebar can be set with parameterization); and the setting of rebar inside the beam will be completed through placing the FF component on the upper (beam) of invisible layer after setting the rebar parameters inside FF component based on the requirements of rebar inside the beam.(see Figure 3).

The third category is additional rebar (reinforced rebar); the reinforced rebar at holes and wall outer contours can be generated automatically based on the overall dimension; however, the reinforced rebar at the hanging bar and binding bar will be added manually (Huang 2015).

Design of pre-buried parts: The pre-buried parts in the wall are divided into three categories: connection pre-buried parts, hydroelectric pre-buried parts and production pre-buried parts, among which, the connection pre-buried parts are divided into pre-buried parts for self connection (such as wall connectors) and for connection with other components (such as normal sleeves); the hydroelectric pre-buried parts including electrical elements, hydroelectric pipeline, pipe fittings etc.; and the pre-buried parts for production including the slings for demoulding, overturning and lifting as well as the parts for fixing and supporting when production.

Allplan software divides the pre-buried parts into four categories: symbol pre-buried parts, liner pre-buried parts, surface pre-buried parts and pre-buried part sets. For the parts made with statistic as per numbers such as lifting bolt, elbow and JDG86 box etc. will be defined as symbol pre-buried parts; for the parts made with statistic as per length such as JDG20 spool, assistant frame of door and window are waterproof rubber strip etc. are defined as liner pre-buried parts (see Figure 4); and for the parts made with statistic as per area such as XPS with thickness of 100mm, form removal-free and outer hanging veneer etc. are defined as surface pre-buried parts; the pre-buried part set is the set made by pre-buried parts and pre-buried parts, pre-buried parts and 3D entity as well as pre-buried parts and rebar, though which, the placement of multiple elements and separate statistic can be realized.

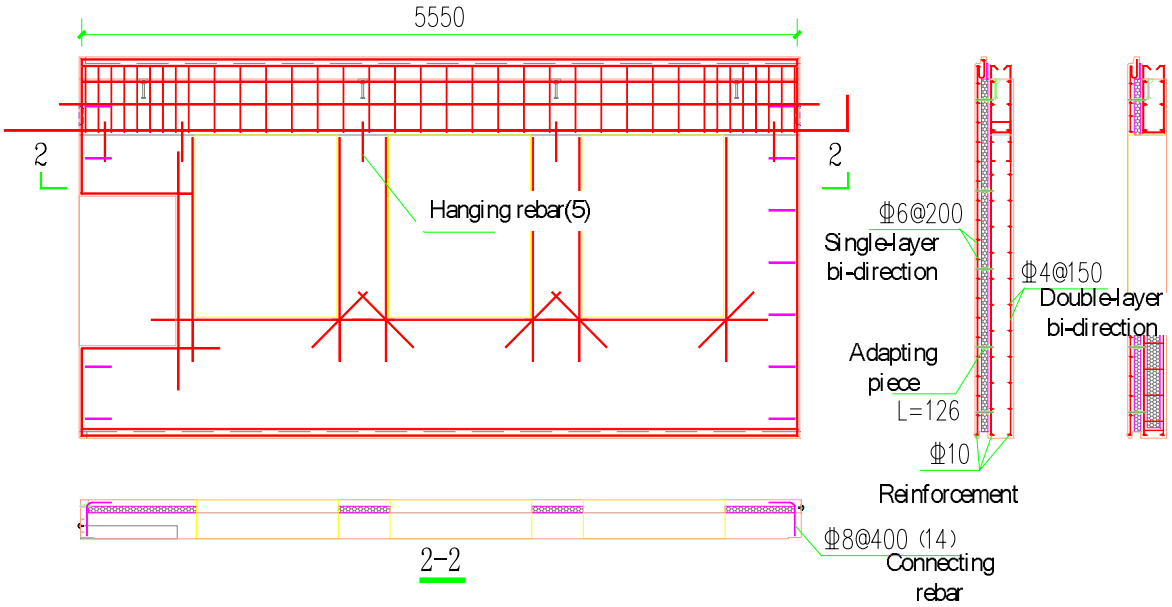

Figure 3. Rebar inside the exterior wall with beam.

For example, in case a pre-buried part set is made of ocellar lifting bolt and anti-punching rebar, the adding of anti-punching rebar for each ocellar lifting bolt after the placement of ocellar lifting bolt can be omitted, and the ocellar lifting bolt will be made with number statistic based

on symbol pre-buried parts and the anti-punching rebar will be made with weight statistic based on the rebar class and diameter, which neither waste the operation time, nor affect the material statistic.

The prefabrication designer completes the shape design rebar arrangement and setting of connection pre-buried parts and pre-buried parts for production and the electromechanical designer sets the hydroelectric pre-buried parts in the traditional design of prefabricated parts. To arrange the hydroelectric pre-buried parts accurately, the electromechanical designer needs to distribute the hydroelectric pre-buried parts to the specific location of prefabricated components according to hydropower construction drawing and layout of prefabricated components, which is really tedious and the hydroelectric pre-buried parts may conflict with the rebar and connection pre-buried parts as well as pre-buried parts for connection, and the negotiation and adjustment between specialties are more, so the design cycle of prefabricated parts is longer.

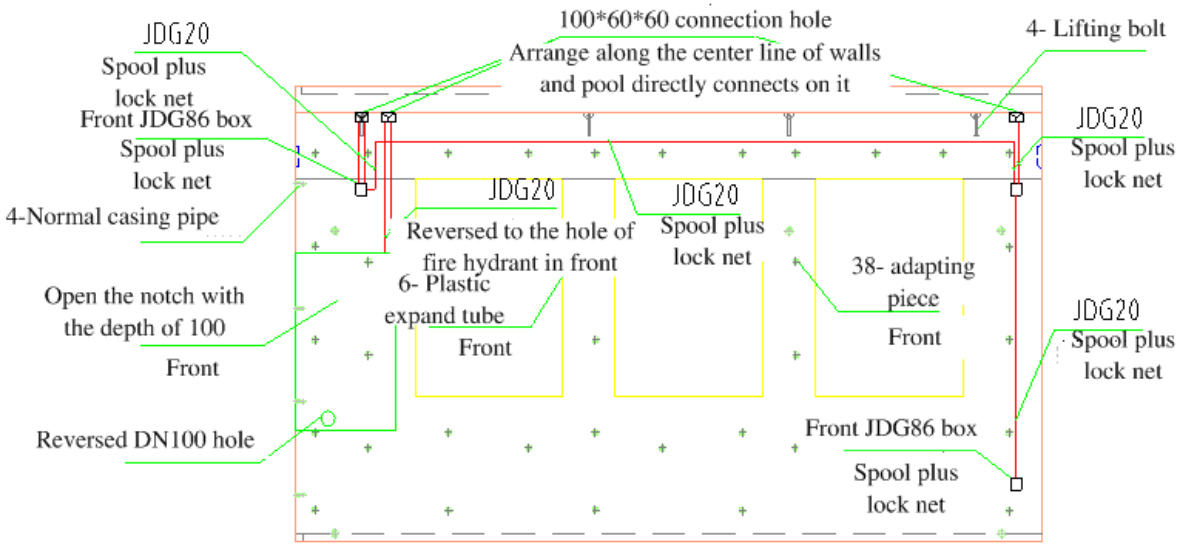

Figure 4. Pre-buried parts inside the exterior wall with beam.

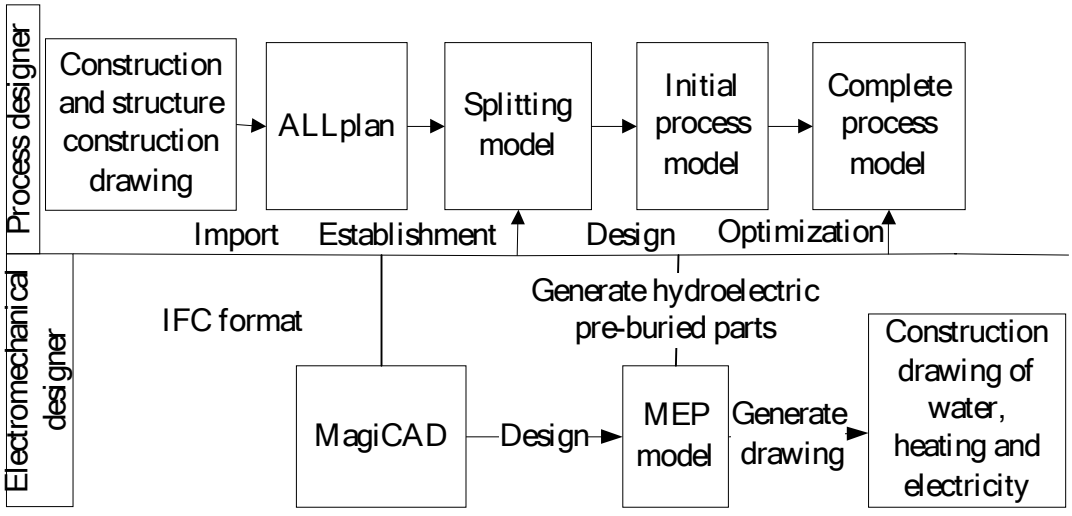

Figure 5. Design flow of pre-buried parts.

For this problem, the new design flow of prefabricated parts is confirmed by adding some

dedicated functions and developing the aided design plug-ins on BIM software selected according to the features of BIM software with the combination of cooperative development and independent research and development: the process designer completes the splitting model in Allplan according to the construction and structure construction drawing, then output the model with fixed common format, and the electromechanical designer imports above model to mechatronic design software (MagiCAD) as design reference, and designs the MEP model collaboratively on the model, with the contents as below: pipeline integrative layout, slotting and tapping and hydroelectric pre-burying design. After completing the MEP model, it will be imported to Allplan platform, and slotting, tapping and placement of hydroelectric pre-buried parts will be made on the initial process model automatically as per MEP model with specific plug-in so as to generate the complete process model. The overall design flow changed (see Figure 5).

Therefore the electromechanical designer does not need to participate in the drawing of process diagram of prefabricated parts (still needs to be audited), which may greatly reduce the design cycle of prefabricated parts.

Collision detection: Collision detection is an essential link for design, and the internal collision detection can be made for the prefabricated components designing on Allplan platform to detect if there is any conflict and collision between rebar inside the component and rebar as well as pre-buried parts and rebar, after which, making statistics on collision times and displaying the collision place. Adjust and modify the design of components according to the results of collision detection so as to ensure the accurate manufacturing of components.

The Allpla platform lacks the automatic collision detection between the components, so it only makes collision and leakage analysis between components on model manually; and the third-party software may be introduced by the software for collision detection between components and made modification on it according to the detection report so as to ensure that there is no problem when installing components.

ANALYSIS OF ALLPLAN GENERATED DATA

Export model: Allplan exports the following file formats: DWG, DXF, IFC, PDF (2D/3D model chart and other data), 3DMAX, sketchUP, and CPI, through which prefabricated component model is designed to apply to the following work such as collision check, construction simulation, electrical and mechanical modeling, 3D display, animation production, and project management.

Export prefabricated file: Allplan exports component production drawing (element plan) and component installation drawing (general layout). This paper focuses on Allplan to generate element plan by one key.

In order to achieve one key drawing generation with Allplan, we first need to set the required layout according to the component's drawing requirements. The design of component with beam external wall is the most complex and the layout is the most complex. The layout of board and special-shaped parts is generally set on one drawing, but a clear and complete expression of the information inside the external wall of the beam requires at least two drawings. The number and position of the views, tables, legends, and labeling plans are defined on each drawing according to the information that you want to convey.

On the wall board production line, first support the mold to determine the shape size, then lay out rebar, and then design pre-buried parts. These three tasks belong to different types of work, so the information of the wall production can be divided into four pieces in two drawings to

express: the first drawing contains technical instructions and component size information, the second drawing contains rebar and pre-buried parts information, each area is provided with relative views, forms, legends and labeling plans.

The view is used to display component information. Each view can define the direction of the view, the displayed contents (rebar, pre-buried parts, symbols, labels, size marking), and the displayed format. Therefore, the three areas can define the displayed contents according to the information they want to convey, and automatically add symbols, labels and size marking to the displayed contents.

The table is used for statistics of component information, including general information (material, area, volume, and weight), all kinds of rebar, pre-buried parts, and specific component information. Therefore, a table is set for three blocks each and the table writes the information to be counted.

The legend is special for detailed statistical materials. For the component using more rebar with beam outer wall, it can be used to make statistics and produce a special bar chart.

The labeling plan is used to add drawing label, as well as generally used node drawing and detail drawing.

After prefabricated component is designed, with a suitable layout, element plan can be generated by one key, individual drawing for some component or batch drawings for all components (He 2011). For different types and sizes of prefabricated component, corresponding layout is needed.

Material information list: The prefabricated component material can be divided into three kinds, the first kind is the main body material: concrete, thermal insulation material, weight loss material, exterior finishing material, etc.; the second kind is rebar material: steel bar, steel mesh and steel strand; the third kind is pre-buried parts: symbol pre-buried, linear pre-buried, and surface pre-buried parts. There are three ways to make statistics of materials in Allplan: Legend, list, and XML file.

Legend: For statistics of a kind of material, such as rebar, a statistical table of rebar materials for a component or the whole project can be generated. The table contains the overall statistics of all steel bars, and the detailed information of each steel bar, such as grade, diameter, bending length, etc., which can be user-defined in the form of expression.

List: Allplan generates prefabricated component list separately by walls, boards and special-shaped parts, and the list contains material statistical information of each component.

XML file: Allplan exports the material information of prefabricated component to the XML file, which contains the same material statistical information as the list, besides contains: project name, contract number, building number, floor number, material code and so on. XML is a dedicated file for ERP system, which can really be used for managing project materials. In practical applications, we need to amend the output source files of XML based on the desired output information, such as a complex prefabricated component with a beam external wall, which may contain two kinds of concrete, two kinds of insulation materials, that is, vertical and horizontal rebar and reinforcing mesh. In the output material information, are the two kinds of concrete exported separately or jointly? Is insulation materials exported by area and volume or by pre-buried method? Is reinforced mesh exported by weight or area? These should be defined in combination with procurement and production.

Export production data: Allplan generates two types of production data for machine processing: rebar processing data BVBS and automatic production data PXML.

Rebar production: Allplan generates a rebar data file for each component. Import the file into

the NC machine tool for rebar processing, and it automatically processes the rebar required by some component.

Automatic production: Allplan exports Unitechnik format data. Import the data into industrial control software, production management, and dock with automated prefabricated parts production equipment. It realizes the full automation of component generation.

ALLPLAN'S ADVANTAGES AND DISADVANTAGES

Improved design efficiency: Allplan's two special technologies make it possible to improve the efficiency of assembly building prefabricated component design: fast generation of mechanical and electrical pre-burying and fast drawing. As mentioned above, Allplan transforms the original manual drawing of water and electricity pre-burying to MEP model automatic generation, which can save the time of a week; after the completion of prefabricated component design, apply appropriate drawing layout to achieve drawing generation by one key and save a lot of repetitive work. In view of CAD design and Allplan design, a prefabricated design time-consuming analysis table is made with 10000M2 square meter housing monomer. (see Table 1).

Table 1. Analysis Sheet of Prefabricated Design Time-Consuming.

Software	Component type	Number of components (pieces)	Process design	Water and electricity pre-burying	Proofread	Review	Amendment	Drawing countersignature	Totally
CAD	exterior wall	143	14	4	7	4	5	1	35
	Beam	148	14	0	6	3.5	4.5	1	29
	Board	345	6	2	4	2.5	2.5	1	18
	Column	82	5.5	0	2.5	2	2	1	13
	Stairs	8	3	0	1.5	1	1.5	1	8
	Interior wall	55	14	4	5.5	3	4.5	1	32
ALL plan	Exterior wall	143	14	6	3	3	1	1	28
	Beam	148	12	4.5	2.5	2	1	1.5	23.5
	Board	345	6	3	1.5	1.5	1	0.5	13.5
	Column	82	5	1.5	1	1	1	1	10.5
	Stairs	8	2	1.5	0.5	0.5	1	1	6.5
	Interior wall	55	13	4	2	3	1	2	25

It can be seen from the table that the design efficiency of assembly building prefabricated component can be increased by about 21% by using Allplan. In addition to saving time in the design phase, proofread and review can be accelerated by various data reports, and the adjustment of the model is directly reflected on the drawing and can shorten the time of amendment. With the improvement of Allplan software function, there is still much room for improvement of design efficiency.

Reduced error rate: Using Allplan for design of assembly building prefabricated

component, the error rate is reduced from the following three aspects:

Firstly, automatic generation of electrical and mechanical pre-buried

In the 2D design platform, the traditional designer draws a construction drawing by space imagination of the brain in the CAD, and then adds the corresponding water and electricity pre-buried parts of the construction drawing to the component drawing of corresponding space on the PC. The designer must be careful because space dislocation is easy to appear in both construction drawing and water and electricity pre-buried drawing. The MEP model automatically generates water and electricity pre-burying parts. As long as the model is correct, the location of designed pre-buried parts must be correct.

Secondly, collision check inside prefabricated component for assembly building. In conclusion, Allplan can carry out the collision check inside the assembly building prefabricated component, helping the designer to discover in time the conflict between this specialty and all fields, and reducing error in the production stage.

Thirdly, collision check between components. With the help of third party software iTWO and Naviswork, collision check between components can be realized, and problems that may be encountered in installation stage are excluded.

Disadvantages: As foreign assembly building prefabricated design software, Allplan's shortcomings are also obvious. The main problems are as follows:

Firstly, not high localization level. Allplan has the function of structure calculation, but has lost value at home because its structural analysis uses the European calculation method, of which analysis results are not recognized in China. Allplan has powerful building modeling function, but it doesn't conform to the domestic drawing requirements in marking and labeling. Therefore, Allplan cannot be used to issue building construction drawings. Besides, statistical methods of all kinds of reports and bills of materials exported by Allplan are different from the commonly used in China.

Secondly, to be improved functional integrity and operation convenience. Allplan does not fully meet the requirements of domestic assembly buildings on prefabricated component design, such as the corner wall and the sandwich wall of more than three layers, which can only be treated in an approximate way. There are three obvious problems in operation convenience: firstly, poor amendment. After the design is finished, amendment is so inconvenient or even impossible that it needs to be redrawn. Secondly, software built-in intelligent component, legend and list do not conform to Chinese users' needs. Custom operation is so complex that needs personnel having programming basics to understand Allplan software code to operate. As an important way to improve design efficiency, the intelligent prefabricated component is developed constantly by users according to their technology development. It is impossible to meet the long-term needs by 1–2 times of customizing. Thirdly, Allplan is a close platform, and no other software can be allowed to develop various plug-ins that improve design efficiency.

CONCLUSIONS

With unique advantages in assembly building prefabricated component design and data export, Allplan is the relatively mature prefabricated component design software in the world at present. Allplan is not only a simple building information model (BIM) that can build prefabricated components, but also an integrated solution of design, model and production data. It realizes design information, design intelligence, and model information application to the whole process of architectural industrialization.

Compared with traditional 2D design platform, Allplan improves the overall design