Application of the BIM Technology in the HVAC Design for an Office Building in Nanjing

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Abstract: Based on the 2-dimensional design, this paper takes an office building in Nanjing as an example to use the BIM technology for the 3-dimensional optimization. With the detailed layout of pipelines, it sets the elevation to replan the original unreasonable designing. Then based on the BIM technology, it uses Navisworks to carry out the collision detection, puts forward the adjustment scheme, and gives types of invalid collision according to the practical experience. And finally it sums up some experiences, which provide optimization scheme for the future design.

1 Introduction

Building information modeling (BIM) is a kind of volume modeling founded by Autodesk company, which sets the preliminary scheme, the construction of the mid and the late operation and management of the project as a whole, and covers all parameters of the project (including construction information, equipment information, construction cycle planning, real estate operation and management, etc.). Now the BIM technology has been gradually changed from theoretical research to practical engineering application, and for construction projects, improving the quality of the solution and the accuracy of the design can reduce the unnecessary investment from all sides in the process of construction, shorten construction life cycle, save resources and reduce construction cost.

Based on an office building project in Nanjing, this paper uses BIM 3D modeling technology to redefine the elevation, to precisely arrange the pipeline and equipment, and to deepen the 2D design. Aimed at the "fight" of the previous pipeline, with the Navisworks software, this paper carries out collision detection, gives solutions to specific problems, and reduces the phenomenon of rework in the later construction, which truly has clear modes and is adjustable on the basis of visualization.

2 Engineering situation

This project is a six-storey office building, the building area of which is about 32680.7 m2 and the building height of which is 23.4 m. The office building is divided into two portions: the overground portion and the underground portion. The building area of the overground portion is 22200 m2, which is mainly used as offices, conference rooms, lecture theatres, and sports places and related facilities; the underground portion is used as garages and equipment rooms, the building area of which is 10000 m2. The architectural renderings of this project are shown in Fig. 1.

Figure 1. Architectural renderings

3 Deepening design of an office building in Nanjing based on BIM

3.1 2-dimensional design

3.1.1 Load calculation

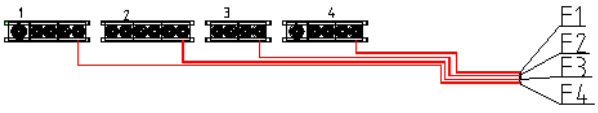
The HVAC load of this project is calculated by Tengen software, and the calculated load and the load indicator of construction area of different seasons are shown in Table 1.

Table 1. Load calculation

	Summer	Winter
Calculated load	2758KW	1686KW
Load indicator of construction area	125W/m2	77W/m2

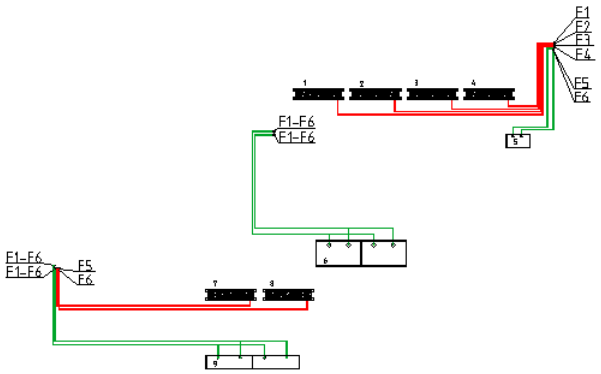
3.1.2 Scheme of the HVAC system

The project consists of a ground floor and 6 layers over ground, in which offices and conference rooms use the primary air fan-coil system, cooperation company offices, general classrooms, blueprinting rooms, printing rooms, reading rooms and the Network Center use the multi-split air fan-coil system, the sports field uses the all air system, and fire duty rooms use unit split air conditioners. The air-cooled liquid chillers and multi-split outdoor units are placed in the 6th floor roof and the 4th floor roof respectively, as shown in Fig. 2 and Fig. 3.



1-4 Multi-split outdoor unit

Figure 2. The conceptual drawing of outdoor units in the 4th floor roof



1-4, 7, 8 Multi-split outdoor unit 5, 6, 9 Air-cooled screw compressor water chiller

Figure 3. The conceptual drawing of outdoor units in the 6th floor roof

3.2 Deepening design based on BIM

3.2.1 Flow of the deepening design (as shown in Fig. 4)

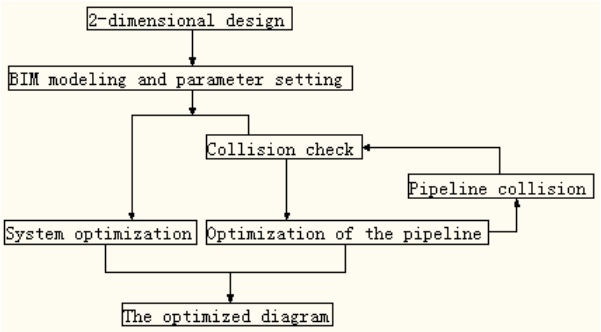


Figure 4. The flow chart of the deepening design

3.2.2 System optimization

There are many pipelines aside mechanical equipments, and because of the simple location layout of the 2-dimensional design, it cannot effectively define the height and lacks the concept of 3-dimensional space, leading to some unreasonable designs [1]. As shown in Figure 5, there are the air and exhaust system and the refrigerant system, including the heat pump air blower unit, the air supply pipe, the exhaust pipe, the condensate pipe, the refrigerant line, the air terminal, etc.

There are many pipeline elbows in the original design, leading to larger system resistance, so the system needs to be optimized. In the system optimization, we readjust the elevation of the original equipment, which is 300mm upwards, and make it closer to the floor, ensuring that there is enough space to arrange the pipeline below the equipment. Pipelines in the air supply pipe outlet and in the air return pipe inlet are respectively inclined 640mm and 430mm downwards, which ensures that the pipeline is below the beam, without a collision. There are 8 elbows in the original design of the air supply pipe and the exhaust pipe, the multiple local resistances of which make the system resistance larger; and in the optimization design of the air supply pipe and the exhaust pipe, there are 6 elbows, which reduces local resistances, and the length of the wind pipe becomes shorter, reducing the on-way resistance. The 3D modeling technology based on BIM optimizes the complex pipeline layout, reduces the systemic resistance, and provides an intuitive and effective design scheme for the construction.

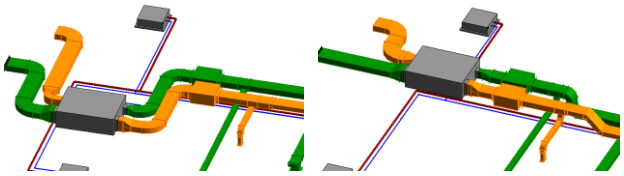


Figure 5. The original system design and the effect after adjustment

3.3 Optimization of the pipeline

Navis Works software is a 3D simulation software by Autodesk Inc., which can read the model data created by BIM 3D software after the extension of data interface, and can provide simulation and analysis for the model. The software consists of 7 function modules, in which the clash detective module can identify collision problems between the construction and the pipeline, and collision problems between pipelines [2]. Collision check is divided into effective collision and invalid collision [3], which need artificial screening.

3.3.1 Effective collision

There are numerous pipelines in the heating and ventilation design, including the air supply system, the air return system, the exhaust system, the circulation supply and return water system, the refrigerant system, the condensate system, the smoke control system, the cooling water system and other subsystems. How to effectively arrange the complex pipelines becomes a hard problem to solve for the 2-dimensional design. If the pipelines are placed improperly, there will be pipeline collisions at the

construction site, which will cause the phenomenon of rework, resulting in waste of construction materials, efficiency decrease, extension of the project schedule and so on. However, based on BIM, the collision detection technology in NavisWorks software can effectively solve these problems.

The 3D models are established in the pre-construction, in which all pipelines are intuitively displayed, and the elevation of equipments and pipelines are set. The BIM models are firstly imported into NavisWorks software, and then each floor is checked as a unit for collision check, generating a list of collision points; and aimed at different collisions, it redefines the elevation, draws the pipelines, and finally uses different schemes to solve the problems. The pipeline collision and adjustment are shown in Fig. 6.

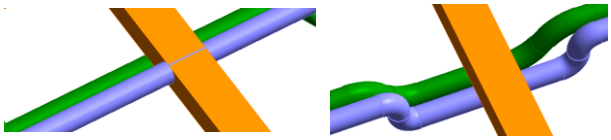


Figure 6. The pipeline collision and adjustment

3.3.2 Invalid collision

The so-called invalid collision is a "collision" appeared in the collision check, which is not because of the faulty design. The BIM technology in our country is in the initial stage of development, and due to the unskilled use of the software by designers, there will be errors in operation; the software itself exists some bugs, and the library family is not yet perfect, so invalid collisions appear in the collision check. These "collisions" need carefully artificial screening, and usually they don't need to be adjusted.

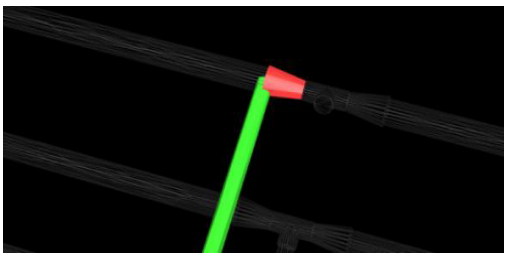


Figure 7. The disoperation

Fig. 7 shows an invalid collision, which is generated by a faulty operation in the drawing process. Fig. 8 is a "collision" produced by the software bug. When connecting the air terminal with the air pipe, it selects the property of the air duct as "connector connection", which will be a "collision" in the collision check; this situation is because of the own problem of the software, which doesn't need to be adjusted. Fig. 9 is a "collision" caused by no suitable connections. When the nominal diameter of the pipeline is larger and the bent downward slope is smaller during drawing downward inclined pipelines, it often meets with a situation which cannot be drawn out; the reason is that the library family of the BIM software is not yet perfect, and sizes of the air pipe accessory and the fitting are just specified, causing a great inconvenience to the design process. When it cannot find the right connection pipe during the drawing process, it will be a "collision" in the collision check, which is not the true sense of the collision and can be ignored.

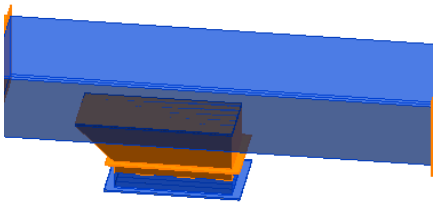


Figure 8. The software bug (connector connection)

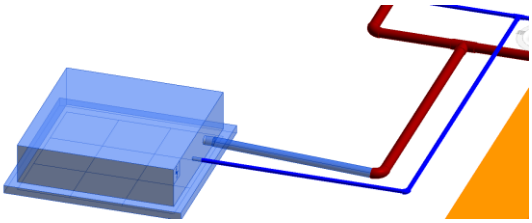


Figure 9. A "collision" caused by no suitable connections

4 Experiences and conclusions of the BIM technology

Compared with the 2-dimensional technology, the application of the BIM technology in HVAC design involves more information, visualization and digitization, and the HVAC design from 2D to 3D takes a revolutionary step. In the 3D models, there is all detailed information of the equipments and pipelines, including size, performance, material, elevation and so on, which greatly improve the design accuracy[4]. The NavisWorks collision check function based on BIM shows the collisions between pipelines, the pipeline and the equipment, the pipeline and the construction. At the design stage, the designers' quickly, precisely and effectively solving collision problems can effectively reduce the construction rework rate and shorten the construction period.

At present stage, the BIM technology is in the initial stage of development, and related standards are not perfect. The BIM technology is not used by the majority of designers. Parts of the domestic design units establish their own material library and library family, but they are only used by their own designers, not shared with the outside world, which restrict the development of BIM to some extent. Hope that the software can improve the library family, perfect the material library, improve the load calculation, combine with the energy consumption analysis software Energy Plus or indoor environment simulation software Fluent etc., make full use of its information advantages and finally achieve the purpose of building energy conservation [5].

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