Research on optimization design of underground garage comprehensive pipeline based on BIM technology

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Abstract. In order to explore the layout of the underground garage comprehensive pipeline and optimize the layout of the underground, this paper takes the complex large underground garage project as the research background, establishes a 3D visual information model by using BIM technology, and proposes the corresponding optimization principle and optimization process to optimize the design of the comprehensive pipeline in the complex area of the underground garage. On the premise of satisfying the use function of the pipeline and the internal height of the underground garage, it also takes into account the beauty and other requirements. The application of the optimized model in this study to guide construction fully meets the acceptance requirements, reflects the superiority of BIM technology, and has good practical guidance significance.

1. Introduction
Since 2002, BIM technology has been introduced into China, and the construction industry in China has set off a wave of informatization. As an important technical means, BIM technology has increasingly entered the construction industry, accelerating the pace of structural adjustment of the construction industry[1]. BIM technology has the characteristics of visualization and coordination, which can avoid the design omission and understanding deviation caused by poor design or unclear description, so as to reduce design errors, improve design efficiency and ensure design quality [2].

As an information technology that will bring tremendous impact and transformation to the construction industry, BIM has been in China for more than ten years and is widely used in integrated pipeline design[3]. At present, the depth and breadth of the research on the design of underground garage pipeline in complex areas of residential projects in China need to be further improved. Therefore, this paper combines the actual project with BIM technology to optimize the design of the integrated pipeline in the complex area of underground garage. By analyzing the characteristics of BIM technology and underground garage, this paper proposes the principle and approach of comprehensive pipeline optimization to explore the application value and development prospect of BIM technology for underground garage integrated pipeline design.

2. Basic characteristics of BIM technology

2.1. BIM visibility
Autodesk defines BIM as an application of architectural design software, which subverts the traditional design mode based on 2D drawings, and also shows a new way of thinking and working[4]. Its visual characteristics generate flat, vertical, and section construction drawings through a 3D model,
which is convenient for finding and reflecting the inconsistent height and position of the building structure and pipeline equipment. By using the visual characteristics of BIM, the horizontal position and design height of the pipeline can be visually viewed, and the best layout way to bypass the collision can be determined, so as to ensure the building clearance height, save construction materials, solve the conflicts between professional pipelines, and make the layout of various pipelines tend to be rationalized and economical.

2.2. BIM collaboration
The coordination of BIM Technology plays an important role in the design of integrated pipeline of underground garage. In the actual design process, different disciplines can share design information in real time based on BIM model. Through the model, the designer can more clearly show the simulated completion of the project. Construction personnel, equipment personnel and supervision personnel can grasp the relevant data and information of the project more intuitively and synchronously. Therefore, it can avoid the understanding deviation of each professional to the drawings, so as to help the whole team to work together efficiently and ensure the accuracy of engineering design information[5].

3. Design features of comprehensive pipeline of underground garage

3.1. Complexity of underground garage design
Because of the complexity of the underground garage structure system, and the mechanical and electrical related professional comprehensive pipeline design is usually a difficult part of the whole project. Especially in the fire protection zone, various pipelines such as cable trays, fire water pipes, domestic water supply pipes, hot water pipes, and exhaust pipes are criss-crossed[6].

Through investigation and research, the main factors affecting the layout and quality control of the comprehensive pipeline of the underground garage are as follows: 1) the structural layout of the underground garage; 2) the condition of the top plate of the garage covered with soil; 3) the floor height setting of the underground garage; 4) the comprehensive trend of the municipal pipeline; 5) the layout of the upper residential building of the garage.

3.2. Limitations of traditional design
In the traditional design, the comprehensive layout of building structure design and equipment pipeline only uses simple lines to express roughly. The elevation changes, relative positions and intersections of various water pipes and ducts are difficult to express clearly, so that the space utilization rate is low, the feasibility and effectiveness of the system scheme can not be ideal, resulting in insufficient feasibility of the actual project construction[7].

In addition, due to the independent design of each discipline and the lack of real-time associated modification function of CAD related software, the design change information of one discipline is difficult to feed back to other professional designers in time, resulting in the complex process of design scheme coordination and seriously affecting the work efficiency[8].

3.3. Limitations of traditional design
Applying BIM technology to the design of underground garage, each profession can carry out fine design according to the real size. In the design stage, the plane layout and height layout of different specialties can be tested through the establishment of the model. The BIM model can visually reflect the distribution of the height of the garage interior, and can find out the location that does not meet the requirements, so as to optimize the design and accurately control the net height in the garage.

4. Application of BIM technology in underground garage

4.1. Project overview
This paper takes the underground garage of a project in Sanmenxia as an example. As parking lot and equipment room, the main structure of the garage is frame structure. The seismic fortification intensity is 6 degrees, the fire resistance rating is grade 1 underground, the garage height is 3.4m, the local floor height is 5.00m, the planned parking quantity is 228, and the design service life is 50 years.

The project includes ventilation system design, water supply and drainage engineering design, fire protection engineering design, strong and weak electricity system design of underground garage. The pipeline design is difficult, and the required pipeline size is large, the bridge width reaches 1600mm, and the width of heating ventilation pipe reaches 2000mm. There are many professional system components, complex pipeline layout, and local areas in the garage are difficult to meet the requirements of garage clear height specified in the specifications. In addition, there are overburden and above ground residential buildings on the top of the garage, the foundation elevation is uneven, and the pipeline is easy to collide with the structural beam and slab.

Because the structure of the project is complex and there are many integrated pipeline systems, it is difficult to ensure the smooth construction in the later stage only using traditional design methods. Based on the above factors and the actual situation, the project adopts BIM Technology for visual collaborative design to optimize the pipelines in the complex area of the garage.

4.2. Application of comprehensive pipeline optimization design

4.2.1. Project design organization structure

As a BIM technology application pilot project, this project requires the submission of traditional 2D drawings and 3D building information models at the same time. Therefore, the traditional method combined with BIM Technology is used for optimization design, and it can provide useful reference for other projects under construction in the same period.

According to the objectives and cycle requirements of the project, the scope of this BIM modeling covers all disciplines of building, structure, water, heating and electricity. According to the 2D design drawings and the actual situation of the construction site, the underground garage water, heating, electricity, fire protection and other professional pipelines are comprehensively optimized, and sufficient space is reserved for later construction and operation.

4.2.2. Project design organization structure

2D drawing design stage: First, according to the task book and relevant specifications, the traditional way is used to complete the construction drawing design of architecture, structure, mechanical and electrical disciplines and the description of comprehensive pipeline layout relationship, and then the BIM model is established and integrated.

3D model collaboration stage: Import 2D construction drawing into Revit to generate reference plane, and build BIM main model based on reference plane. After the professional modeling of architecture and structure is completed, based on the linked model function in Revit, link the central file to the professional design file, determine the spatial location of the professional pipelines through the central file, and create the professional sub models (Figure 1). Each professional model is integrated, and then the integrated pipeline is adjusted and optimized. Because of the link function, the local adjustment of the model can be reflected in the overall BIM model in real time to ensure the accuracy of the local adjustment information.
4.2.3. Pipeline collision detection and drawing problem report

Import BIM model into Navisworks for collision detection, set different professional components as detection objects and generate detailed collision detection report. In view of the problems shown in the report, the BIM model is modified, adjusted and updated in real time, and then collision check is carried out again to ensure the elimination of conflicts between disciplines alternately.

According to the collision detection report, the important problems affecting the building function, pipeline layout and later construction are comprehensively sorted out, including 7 categories of civil engineering specialty and 11 categories of mechanical and electrical specialty. The problems reflected in the report mainly include the following aspects: the drawing design description is inconsistent with the construction plan, the pipeline size and location are not clearly marked, the design space of electromechanical pipeline is insufficient, the system diagram is inconsistent with the plan, and the drawings of different disciplines at the same location are inconsistent.

4.2.4. Principle and approach of comprehensive pipeline optimization

When optimizing and adjusting the comprehensive pipeline of the project according to the main problems shown in the collision detection report, the following layout principles and acceptance regulations shall be followed:

1) The water supply and drainage and fire protection pipelines shall be laid in parallel with the ventilation exhaust pipes and cable trays, and the lowest point elevation of the pipeline is greater than the lowest point of the ventilation exhaust pipe.

2) During the adjustment process, the height of the pipeline shall be raised as much as possible to reduce the bending and turning in the direction of pipeline layout, avoid complicated construction steps, and reserve at least 500 mm of construction and maintenance space.

3) The water and heating pipes shall be designed in parallel with the structural beam, and a distance of not less than 500 mm is reserved to ensure sufficient space for the pipeline to cross. The pipeline should be turned up by 45° bend.

Considering the construction space, pipeline trend, design specification, acceptance standard, cost and other aspects, following the concept of reasonable layout, professional coordination, beautiful space and convenient maintenance, the actual design of the underground garage project of the project mainly adopts the following three ways to optimize:

1) The data sharing center will send a move or delete request to the receiving end of the pipeline components in collision, and solve the collision problem through interactive communication within the software. For example, the collision between the ventilation pipe and the structural beam is solved by sending a move request (Figure 2).

2) Through the collision problem reflected in the collision inspection report, locate the collision reason according to the collision component ID number and notify the relevant professionals to coordinate and solve the problem. The collision between equipment and building structure or between pipeline equipment is generally complex. By checking the specific collision component ID number, the pipeline or equipment in collision can be coordinated and optimized accurately.
3) The problem of collision and unreasonable layout of pipeline complex areas such as equipment fire zone, public area and equipment room connection, combined with the principle of integrated pipeline layout and related specifications, gives targeted recommendations for coordinated optimization of component location (Figure 3).

![Figure 3. Collision between heating ventilation pipe and structural beam](image)

![Figure 4. Intersection layout of pipeline in complex area](image)

**4.2.5. Analysis of pipeline optimization design in complex area**

Considering the limited construction space of the actual project site, it is necessary to check the pipeline installation operation space in the design process. According to BIM model, check the installation and construction space of each professional pipeline, and find out the possible problems in the construction process in time, such as the unreasonable layout of pipeline spacing or the operation space does not meet the requirements.

In addition, in combination with BIM model and site conditions, reasonably arrange the sequence and occupied space of each professional pipeline installation work. Ensure that the pipeline equipment installed first does not affect the construction space of subsequent work. For example, the pipeline layout at the intersection of the pipeline is complex, resulting in insufficient construction space for the upper water supply pipe and fire water pipe, so it is necessary to install the upstream pipeline at the intersection to ensure the smooth construction (Figure 4).

**4.2.6. Optimization concept and measures of net height in garage**

According to the "Residential Building Code" requirements, the net height of the lane in the residential underground garage should not be less than 2.2m, and the net height of the parking space should not be less than 2.0m. In combination with design specifications and project quality acceptance requirements, the core concept of net height optimization in the project garage is as follows: The overall layout of the garage shall be reasonable, the height of the beam section shall be controlled or the upturning measures shall be adopted, so as to reserve enough space for the mechanical and electrical professional pipelines to ensure the internal clear height of the garage.

Combined with the other two underground garage projects under construction in the same period, under the traditional design, the net height in the garage can only be estimated locally, which is difficult to consider the problem of insufficient net height globally. In this project, combined with the visibility and coordination characteristics of BIM Technology, on the basis of preliminary adjustment of the comprehensive layout of pipelines, further optimize the comprehensive layout of pipelines according to the design requirements, find out the situation of insufficient net height and put forward the optimization scheme in time.

**4.2.7. Difficulties and optimization breakthrough in comprehensive pipeline design**

The main difficulties in the comprehensive design of the pipeline of the project are: the internal structure of the garage is complex, and the elevation of the equipment pipeline and the clearance height in the garage are difficult to meet the specification requirements.

Combined with the analysis of the other two projects under construction in the same plot, the modification amount of traditional design drawings used to guide the construction is large. In this
project, BIM Technology is applied to optimize the spatial layout of pipelines, coordinate and optimize the conflicts between pipelines and building structure, accurately control the garage clear height, and avoid unnecessary modification and adjustment in the construction process. According to the statistical analysis of relevant data, the project is optimized by BIM Technology and used to guide the construction on site. The construction period is nearly two weeks ahead of schedule and the cost is 7% less than the total investment.

5. Conclusion and prospect
In this paper, BIM Technology is applied to the optimization design of integrated pipelines in underground garages. Firstly, the collision inspection of integrated pipelines in complex areas of underground garages is carried out and the corresponding optimization principles and approaches are proposed. Secondly, optimize the pipeline construction space in the complex area to ensure the smooth construction. Finally, for the areas in the garage that do not meet the requirements of clear height, the comprehensive pipeline is further optimized through the clear height inspection and analysis. Therefore, all the above difficulties, collision and insufficient net height are successfully solved.

During the optimization research process, it was found that the inventory of the component model in the BIM-related software was insufficient, and the designer could not achieve the desired effect in the actual operation. At present, most of the engineering projects are based on the traditional 2D drawings to establish 3D models, and the use of BIM Technology to directly produce construction drawings is still in the transitional stage. How to use BIM Technology for forward design to provide more efficient and practical services for the optimization design of underground garage comprehensive pipeline, and make corresponding reserved optimization measures for the pipeline adjustment or increase that may occur in the future operation and maintenance process in advance is worth further research and discussion.

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