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BIM-Based Parametric Modeling: Design Innovation and Project Demonstration of Special-Shaped Steel Structure Engineering

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Abstract. In the intricate landscape of special-shaped steel structure design, where complexity and uniqueness are paramount, the integration of Building Information Modeling (BIM) has proven to be a game-changer. Specifically, BIM significantly expedites the creation of steel structure models and streamlines the engineering drawing process, enhancing both accuracy and efficiency. This paper spotlights a case study from a subway station project in Shanghai, leveraging the inherent parametric modeling capabilities of Revit software to design complex steel structures. Our investigation explores the methodology and foundational principles guiding the development of parametric special-shaped steel structure models. We emphasize the critical importance of the initial design stages in laying the groundwork for project success. The advantages of employing parametric technology are underscored, notably increased productivity and reduced labor costs, illustrating its potential to streamline complex steel structure projects. Furthermore, the research illuminates how parametric technology can profoundly reshape the steel structure industry. By fostering a more agile and cost-effective design and construction process, it optimizes resource allocation and accelerates project timelines. This makes parametric technology an indispensable element in the ongoing modernization of construction practices. The insights gleaned from this study contribute to the expanding body of knowledge on the practical application of BIM and parametric modeling in complex engineering projects. Our findings offer a roadmap for future advancements, guiding the field towards more sophisticated and efficient design methodologies.

Keywords. BIM, parametric modeling; special-shaped steel structure, a subway station in Shanghai

1. Introduction

In order to meet the requirements of artistic modeling and decoration of modern architecture, special-shaped steel structure are produced. Special-shaped steel is often used in shopping malls, comprehensive buildings, stadiums, urban sculptures, gate building modeling, toll stations, building roofs, large steel structure stairs, etc. Generally, the space geometry model of special-shaped steel structure cannot be expressed by elementary function, which requires structural engineers to spend several times or even dozens of times to design. Structural engineers should make repeated deliberation when making plans in the early stage to avoid unnecessary delay of

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construction period [1]. In order to solve these problems, 3D modeling calculations are generated accordingly.

Steel structural components, with its light weight, convenient forming and cost-effective characteristics, occupy an increasingly important position in new building products. In the core content of steel component design, lofting and unfolding technology is the key link to ensure the precise forming of the component [2,3]. Improving the calculation efficiency and drawing accuracy of the lofting and deployment of steel components is essential to optimize the processing quality and improve labor productivity.

With the rapid development of computer hardware and software technology, three-dimensional design technology has emerged in many industries, among which building information modeling (BIM) technology is particularly prominent, and its application scope in the whole life cycle of engineering is rapidly expanding [4,5].

Based on BIM technology, the development of a software platform integrating the design of special-shaped steel structures and the production of detailed drawings not only significantly improves the design efficiency, but also greatly enhances the production capacity and market competitiveness of enterprises. Its application prospect and value are self-evident. In the field of 3D modeling software, UG and CATIA, as industry leaders, support parametric modeling functions that show incomparable advantages over traditional CAD modeling [6,7].

In recent years, in order to meet the specific needs of the construction industry, a number of software or plug-ins tailored for architects have emerged, such as Digital Project based on CATIA platform and Grasshopper based on Rhino platform. These tools have shown strong potential and practicality in the early stages of building structure design, especially in curtain wall segmentation and form generation. [8]. The application of parametric modeling software in the early stage of building structure design is becoming more and more extensive, not only limited to curtain wall segmentation, but also extended to key links such as morphological optimization [9].

Although the current modeling software on the market performs well in some aspects, such as parametric modeling functions such as longitude and latitude segmentation, it is often difficult to meet the comprehensive parametric requirements when dealing with specific projects, especially the design of special-shaped steel structures [10]. In order to solve these limitations, this paper proposes a innovative solution based on REVIT software platform. Through its built-in JAVA programming language, it realizes the visual model creation, parametric design of special-shaped steel components, and automatic drawing and labeling of the expansion diagram based on the calculation formula results. Finally, the three-dimensional visual model and the two-dimensional expansion diagram are presented in the same space, forming an intuitive comparison and reference.

Using the built-in JAVA programming language of REVIT software platform for secondary development, we successfully created a three-dimensional visualization model of special-shaped steel components. The model not only truly and comprehensively shows the solid form of the component, but also supports multi-angle observation, which provides an intuitive design reference for the designer. At the same time, the expansion diagram drawn automatically by calculating the results of the formula has reached the high standard requirements of modern design in terms of design accuracy and generation speed. This integrated solution displays the visual model and the two-dimensional expansion map in the same space, which greatly

improves the efficiency and accuracy of the design, and proves the powerful potential and practical application value of REVIT software as a design tool.

2. Applications and Characteristics of BIM Parametric Modeling in Steel Structure Engineering

The application of BIM-based parametric modeling technology in special-shaped steel structure engineering has greatly promoted the innovation of design and the efficiency of construction. This technology allows designers to quickly generate a variety of design solutions by adjusting key parameters, especially when dealing with complex and non-linear structural forms, to explore a wider creative space and promote design flexibility and diversity.

Innovation in the extension of a building's life is paramount. Simultaneously, the environmental analysis capabilities of parametric models, including energy consumption analysis and sunlight simulation, significantly support green design choices, thereby enhancing the sustainability of special-shaped steel structure projects.

BIM parametric modeling technology has brought revolutionary changes to the design, construction and operation and maintenance of special-shaped steel structure engineering through its data-driven accuracy, multi-professional collaboration capabilities, conflict detection and optimization functions, and support for environmental sustainability. The overall quality and efficiency of the project have been improved, and the far-reaching impact and application prospects in the construction industry have been demonstrated.

In order to verify the practical application effect of REVIT software in the design of special-shaped steel structure, we applied it to the shape-finding design of the platform roof of a rail transit project in Shanghai. The practical results show that the REVIT software performs well in the design process, not only the operation is convenient and stable, but also the generated drawings meet the industry standards. It is a successful application example of secondary development technology in the field of steel structure design. By combining the parametric modeling function to design the special-shaped steel structure, we not only improve the flexibility and efficiency of the design, but also provide an innovative idea to improve the production capacity of enterprises.

3. Project Overview

Taking a subway station project in Shanghai as an example, the lower part of the project is a concrete structure, and the platform floor ceiling adopts an arched steel structure. The total length of the structure is 157 meters, the total width is 29.44 meters, and the structural elevation is 14.28m ~ 25.48m, as shown in figures 1~4. The special-shaped steel junction structure of the subway station is a frame-core tube structure, and the skirt building is a frame structure. The total steel consumption of the steel structure is about tens of thousands of tons, and it consists of 11 parts such as outer frame steel column steel beam, transfer truss, ring belt truss, cap truss, tower crown, awning, core tube inserted steel column and shear wall steel plate, skirt building steel column steel beam, banquet hall truss, canopy, roof steel frame, etc. Steel structure components

about tens of thousands of pieces, so the arch steel structure design is the project's important and difficult point.

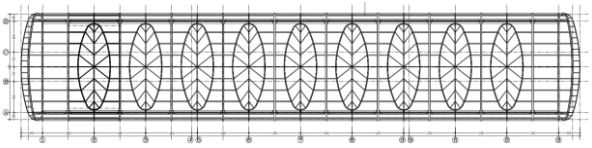


Figure 1. Structure Plan.

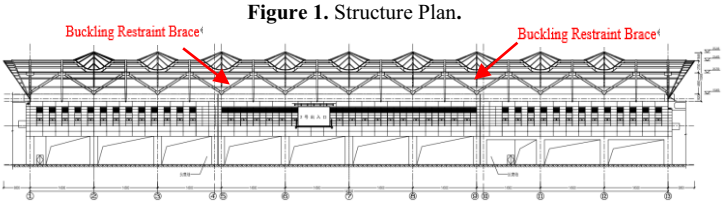


Figure 2. Structural Elevation.

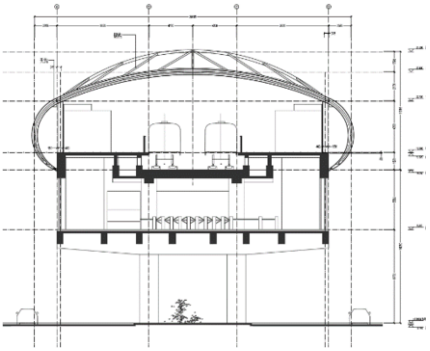


Figure 3. Structural Section.

Figure 4. Appearance of a subway station in Shanghai.

4. Parametric Modeling Design

4.1. Independent Variable

Under the condition that the outline of the basic model is guaranteed to remain unchanged (such as the tangent of the three arc beams of the main arch, etc.), some other parameters can be adjusted according to the requirements of the architect. For example, in the following figures 5-6, the parameters 'top height', 'half span width', 'arch height', 'horizontal gap of arc beam' and 'vertical gap of arc beam' are shown.

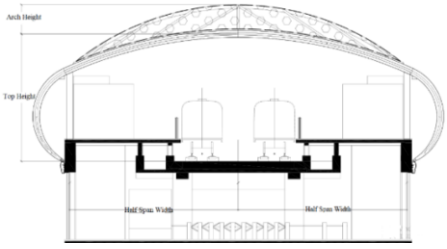


Figure 5. The independent variable of the main arch.

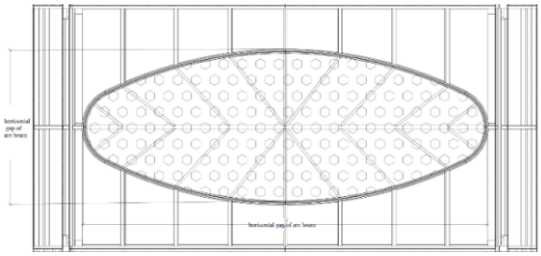
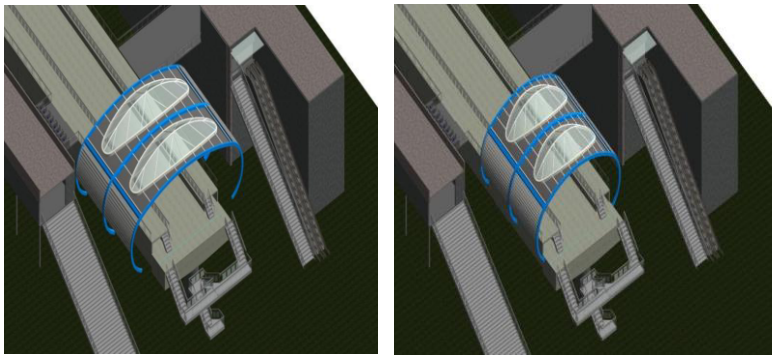


Figure 6. Independent variables of the grid membrane.

4.2. The Demo Process of Parameterization

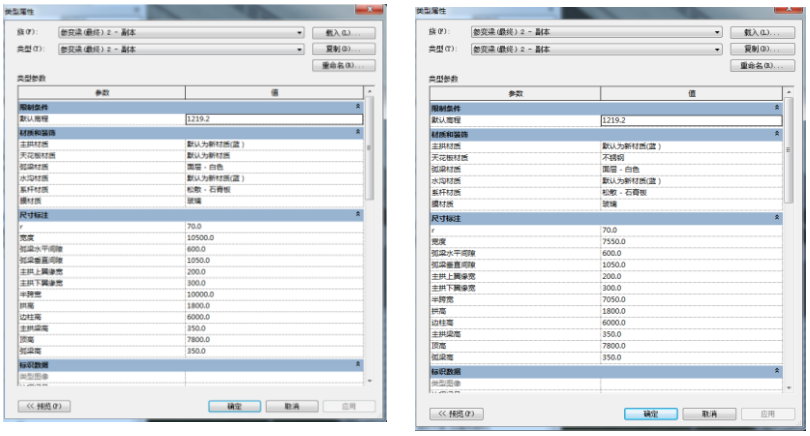
One of the characteristics of BIM technology is parametric technology. According to the characteristics of the technology, this paper uses parametric modeling technology to carry out modeling research on heterosexual steel structures. Parametric model creation can not only greatly improve the speed of model generation, but also greatly improve the speed of model modification, it can be said that its modeling methods and processes can be reused. The following mainly introduces the design process of the outline of the platform ceiling of a site project of Shanghai rail transit station.

In order to ensure that the basic model contour of the ceiling is unchanged, a parametric ceiling is arbitrarily built, which is obviously wider than the concrete support underneath. In addition, the height of the arch on the membrane, the cross-sectional dimensions of the main arch arc beam and the tie rod can be modified according to the needs of the designer. By modifying the parameter table of the independent variable in Revite, the half-span width of the ceiling is changed. The specific effect is shown in figure 7. The specific operation is shown in figure 8. The top height of the ceiling is changed in the parameter table of independent variables to make the arch look more coordinated and reasonable, and the half span width is changed to 7550. Then the top height is changed to 4800. Finally, by changing the parameters of "horizontal gap of arc beam" and "vertical gap of arc beam", the size of the middle grid membrane area can be, and the modified effect is shown in figure 9.



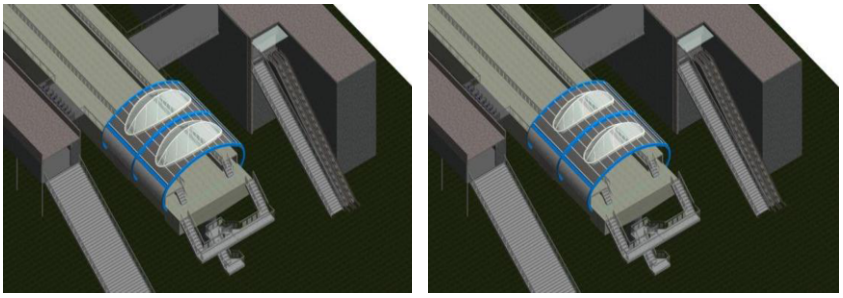
(a) (b)

Figure 7. Revised comparison drawing of half span width of ceiling,(a) with top height of 7550, (b) with top height of 4800.



(a) (b)

Figure 8. Modification of the half-span width of the ceiling, (a) with a top height of 7550 and (b) with a top height of 4800.



(a) (b)

Figure 9. Modified control of the middle grid membrane area. (a) Before modification, (b) After modification.

4.3. Demonstration Principle of Parameterization

In Revit software, the basic elements are "reference point" and "reference line". First, points are built. The lines are seen from the points and the lines are seen from the lines. For example, figure 10. Each arc of the following three main arches is generated by 3 reference points. Each arc has a datum plane in the horizontal and vertical directions, which is equivalent to the X axis and Y axis on the coordinate system, the coordinates of the other 9 reference points are defined as (X1-Y1)~ (X9-Y9). First determine the independent variable, in this main arch, by adjusting the width and height of the main arch; Y3 is defined as the top height, and then X1 X2 X8,X4 X5 X9 is defined as the half span width. However, the coordinates of other reference points should change with the top height and half span width under the premise of meeting the basic rules (such as the 3 arc tangent, etc.). The difficulty is mainly to explore the relationship between the coordinates of other reference points and the independent variables. After defining the main arch path, then define the length and width of the rectangular section on the path, and finally execute the scan command. In this way, the parametric model of the main arch steel structure of the cross-frame, arch height and the parameters of the main beam cross-section argument is established. The basic idea based on the structure generation

process is similar to the scripting language function in the program, which defines the researcher's years of drawing experience in the form of a process tree, and then records the basic model entity to be generated through operations such as Boolean operations. This operation record can be reused. The modeling method based on the generation process is mainly used in three-dimensional solid modeling, and this paper creates a visual model of special-shaped steel components based on the idea of generating mileage. The basic idea of variable geometry is to set various constraints on the model to achieve control over the model. Such constraints include dimensional constraints and geometric relationship constraints. Dimensional constraints mainly control the size of the model, such as width, length, height, radius, etc. Obviously, changes in size will inevitably lead to changes in the model. Geometric relation constraints define the shape of the geometric model mainly by controlling the geometric relations of some basic elements in the complex model.

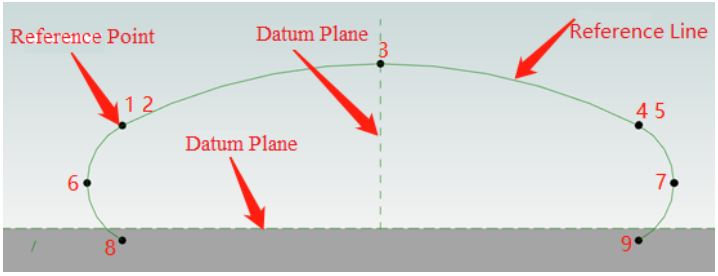


Figure 10. Datum Points and Plane for Design.

5. Conclusion

In this paper, based on BIM technology, the development and research of heterosexual steel structure is carried out, and the three-dimensional parametric model and two-dimensional detailed drawing display of special-shaped steel components are realized with the help of the provided interface. The software platform has a strong advantage in the transformation from three-dimensional to two-dimensional, which is suitable for the software platform of two-dimensional and three-dimensional display at the same time. At the same time, the combination of platform and technology is a powerful tool for solving complex drawing problems. Using its own drawing means, combined with the object drawing process, the special-shaped steel component modeling template library and the expansion drawing template library are created. By calling the template library to create a model, convenient, fast and accurate. Compared with the traditional method, the accuracy of modeling of special-shaped steel members is improved, and the workload of workers and design errors are reduced.

In this paper, taking a subway station project in Shanghai as an example, the parametric design of special-shaped steel structure is carried out based on Revit software, and the process of establishing the parametric special-shaped steel structure model is mainly analyzed, which shows the prospect of parametric technology application. However, there are still many constraints in the promotion of the application, mainly because the theory of parametric design is still immature, in the final analysis, the new design technology is not mature enough. It is precisely because

of this immaturity and pioneering nature that more and more architects are obsessed with it, and it will also lead the trend of architectural design in the future.

In summary, the secondary development technology based on REVIT software platform shows significant advantages in the design of special-shaped steel structures, which not only improves the accuracy and efficiency of the design, but also provides new possibilities for the production capacity and design innovation of enterprises. Through the practice and analysis of this paper, we have proved the efficiency and reliability of REVIT software and its parametric modeling function in dealing with complex structural design. These technologies have greatly promoted the innovation of design by adjusting key parameters to quickly generate diversified design schemes, especially when dealing with complex and non-standard structures. In the construction phase, the automatically generated detailed drawings and 4D construction simulation not only improve the accuracy of construction drawings and the efficiency of the construction process, but also optimize the resource scheduling, reduce site changes, and ensure the safety of construction. In addition, model-based bill of materials and cost estimates provide accurate data support for project budget management.

In the future, the application of BIM-based parametric modeling technology in special-shaped steel structure engineering is expected to be further deepened and expanded. Advances in technology will drive the performance of BIM software, enhancing its ability to handle more complex structures and larger amounts of data. At the same time, with the integration of cloud computing and big data technology, real-time updates and remote access to model data will become more convenient, promoting efficient collaboration across regions and teams. With the continuous improvement of technology, the penetration rate and application level of BIM parametric modeling technology will be significantly improved, and the construction industry will develop in a more digital, intelligent and sustainable direction.

References

[1] Chen Z. Development of special-shaped steel structure software based on BIM. Dalian University of Technology, 2013.
[2] Li J, Luo YF. Stability analysis of special-shaped steel structure. Structural Engineer. 2012; 28(06): 14-18.
[3] Liu Y, Li YQ, et al. Research and application status of BIM technology. Structural Engineer. 2015; 31(04): 233-241.
[4] Jia LM. Research on building parametric modeling based on Revit and TR-Arch software integration. Anhui Architecture. 2019; (05): 182-185.
[5] Ming L, Fu J, Hu ZH, Shao L, Tian FH. Innovation and practice of BIM intelligent rebar sample technology in housing construction project. Construction Technology. 2019; 48(04): 70-72.
[6] Liang JJ, et al. Application of BIM technology in complex special-shaped steel structure project. Construction Technology. 2018; 514(15): 40-43.
[7] Zhu HL, Ding YL, Liang QH, et al. Design technology and system development of building seismic support and hanger based on BIM. Engineering Construction and Design. 2018; (23): 30-32.
[8] Li YY, Cheng ZT, Yang MQ. Application of steel structure processing technology based on CATIA-BIM in bridge engineering. Sino-Foreign Highway. 2019; 39(01): 117-121.
[9] Feng HF. Based on BIM virtual construction technology and construction period monitoring analysis in steel structure construction application research. Chongqing University, 2016.
[10] Zhou C, Zhao F, Chen M. Application of BIM technology in large-span special-shaped truss steel structure project. Construction Technology. 2016; 45(21):78-81.