Research on Steel Structure Deeping Design Application Practice

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Abstract. The node forms of a steel structure project are complex and changeable, from small beam connection nodes to large joist and steel column connection nodes, there are all kinds of nodes, and it is quite difficult to deepen the design. The Deeping design always plays a vital role in the steel structure construction, and the quality of its design will be directly related to the strict and effective implementation and execution of the design drawings to some extent, so as to further supplement and improve the construction drawings. Therefore, this will be directly related to the construction progress of the whole project and construction quality. This paper combines the actual project, to deepen the design of the problems to be considered for analysis, and put forward countermeasures. Through the project comprehensive application, confirm the feasibility of relevant countermeasures, and hope that the follow-up similar projects can have reference and help.

Keywords. Steel Structure, deeping design, complex nodes, practical research.

1. Introduction
A tower has ninety-nine floors above ground, and the height of the main structure is 440 meters, which is an outer frame with belt truss + core tube (steel bracing) + outrigger truss. The commercial podium is six floors above ground, with cast-in-place reinforced concrete frame knot. The basement is a three-story, partially mezzanine, cast-in-place reinforced concrete frame shear wall structure. The steel structure of the project is mainly distributed in the tower and the podium, with a total steel consumption of about 73,340 tons. The steel structure of the podium is mainly in the form of section steel, section steel beams, section steel columns and trusses in concrete beams and columns. The steel structure of the tower is mainly in the form of giant steel columns, steel concealed columns in the core tube, and steel concealed beams in the core tube, steel plate shear walls, pressure plate, steel frame beams, outrigger trusses, conversion trusses, belt trusses and braces.

The Deeping design is the premise of steel construction, and its good or bad directly determines the degree of difficulty of construction of the project. In view of the complexity of the steel structure of this project, the authors have deliberately strengthened the requirements for deepening the design [1].

2. Overall Process of Deeping Design
Steel structure deepening design, i.e. steel structure detailed design [2]. It is carried out after the design of steel structure construction drawings, and the detailed drawing designers perfect the structure of the members according to the arrangement of the members, the cross-section and internal force of the members, the structure of the main nodes and various relevant data and technical requirements.
provided by the construction drawings, and in strict compliance with the provisions of the relevant drawings and specifications. According to the principles of production conditions of the manufacturer and on-site construction conditions, and consider the transport requirements, lifting capacity and installation conditions, determine the segments of the components. Finally, by using the professional steel structure deepening design drawing software, the overall form of the components, the size and requirements of the parts of the components, as well as the connection between the parts, detailed performance to the drawings, so that the manufacturing and installation personnel to view the drawings can clearly understand the structural requirements and design intent, to complete the processing of the components in the factory and the field assembly installation. Overall flowchart for deepening design is show as figure 1.

![Overall flowchart for deepening design.](image)

**Figure 1.** Overall flowchart for deepening design.

3. Deepening Design Software

3.1. Software Configuration

Steel structures deepening software resource kit shows as table 1.

| Serial Number | Name       | Function                      |
|---------------|------------|-------------------------------|
| 1             | XSTEEL     | Modeling and drawing software |
| 2             | AutoCAD    | Modeling and drawing software |
| 3             | SAP2000    | Structural Design Software    |

3.2. Introduction of the Software

Based on the experience of deepening engineering design, the deepening design of this steel structure project is carried out by Xsteel, the software from Finnish company Tekla.

Xsteel not only has a powerful detail design related functions but also can create any complete three-dimensional model, as well as automatically create the model to generate machining details, installation layout, all kinds of material reports, and CNC machine data [3]. All of the beams, columns, plates, and bolts in the model are intelligent and can be modified automatically to make adjustments. Xsteel allows multiple users to work on the same model.
The Xsteel software also provides a series of interfaces to other engineering software [4]. Through these interfaces, the design process can be effectively connected to structural analysis and design software and manufacturing CNC systems, thus sharing information throughout the entire process of project implementation, which greatly improves efficiency and reduces project risks.

4. Analysis of the Key Difficulties of the Project’s Deepening Design

4.1. Overview of the Deepening Design of the Project

The project tower has ninety-nine floors above ground, and the height of the main structure is 440 meters, which is an outer frame with belt truss + core tube (steel bracing) + outrigger truss. The outer frame is made of irregularly inclined cylindrical steel tube concrete columns with a large cross-section and six belt trusses distributed along the floor heights. The inner cylinder is mainly a steel plate shear wall structure, and the inner cylinder and outer frame are connected by multi outrigger truss and various steel beams with complicated and changing nodes, ranging from small beam connection nodes to large truss and steel column connection nodes, which makes it difficult to deepen the design. Besides, the outer frame columns and trusses are all large members, and the transport and preassembly of members put forward high requirements on member segmentation.

4.2. Typical Node Deepening Design

In addition to some conventional nodes, there are also the following complex nodes in this project. With the existing deepening design software, it can deepen reasonably according to the deepening principles, and according to the design intent for fabrication and installation. Some typical nodes deepening design show as Table 2.

| Node Name                          | Complex Node Detail Drawing | Node Deepening Diagram |
|-----------------------------------|-----------------------------|------------------------|
| Typical Nodes in Round Top and Square Bottom | ![Diagram](image1.png) | ![Diagram](image2.png) |
| Branch Nodes of the Column        | ![Diagram](image3.png)      | ![Diagram](image4.png) |
| Bending Torsion Column Eccentric Nodes | ![Diagram](image5.png) | ![Diagram](image6.png) |

Table 2. Typical node deepening design.
4.3. Organizational Structure and Staff for Deepening Design

Organizational structure and staff for deepening design show as table 3.

Table 3. Organizational structure and staff for deepening design.

| Serial Number | Staff                        | Function                                                                                                                                                                                                 |
|---------------|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1             | Project Leader               | Responsible for the development of the general principles of the project deepening design, design key nodes and key process of the drawing expression form; responsible for the overall quality of the project deepening design drawings; validation of deepening design drawings; responsible for the coordination and communication with the original design units. |
| 2             | Process Engineer             | Specifically responsible for the implementation of the welding principle process. And according to the principle of welding process to prepare welding process assessment plan, to develop the welding position, the thickness of the plate, the welding method, the welding process of the material, to determine the specific form of the different weld bevels, all kinds of weld mark forms, etc., as well as proofreading the deepening design drawings. |
| 3             | 3D Modeling Group            | Under the guidance of the project leader, the 3D modeling of the entire steel structure of the project is carried out, the original design drawing dimensions are rechecked, the design of the node form is checked, feedback of error information is provided, and the model of the entire structure including the detailed nodes is finally completed as a reference for the construction drawings. |
| 4             | Structural Design Group      | Under the guidance of the project leader, carry out inspection and other structural analysis and design of typical, important nodes and tooling, temporary reinforcing members, feedback calculation results, propose revisions, compile calculations and submit them to the project leader and original design unit for approval. |
| 5             | Detail Drawing Group         | Under the guidance of the project leader and the cooperation of the 3D modeling group, the corresponding drawings are exported from the 3D model, and the drawings are proofread and adjusted, feedback error information, add process information, and finally complete the deepening of the steel structure design drawings out of the work. |

5. Liaison and Presence Service Measures of Deepening Design

5.1. Technical Services for Processing

To organize the main design staff in the deepening design before the start of processing and production, and processing and production staff jointly organized a drawing meeting, and arrange deepening design staff stationed in the factory, processing, and production process of the drawing problem at any time to be answered [5].
5.2. Technical Services for Transport
The design of the lugs is based on the position of the components to be transported and the weight of
the components. To ensure the safe handling of the components, the position of the center of gravity of
each transport unit should be given in the detail design and marked for spraying.

5.3. Technical Service for On-Site Assembly and Installation
To organize the main design personnel to carry out the design of the assembly and installation
personnel before the start of the assembly and installation of the design, and assembly and installation
personnel to organize the drawing meeting, and according to the meeting to review the views of the
drawing modification, and deepening of the design personnel stationed at the site to help solve the
problems arising in the assembly and installation process.

5.4. Technical Services for other Professions On-Site
The personnel stationed at the site make clear communication and coordination with the civil
construction, curtain wall, mechanical and electrical decoration, and other professionals, and regularly
participate in their professional drawing review, technical exchange meetings, handover meeting; with
the steel structure associated with the changes, modifications, etc. reached at the first time to deepen
the design department, so that the steel structure deepening design on time to modify and implement
[6].

6. Deepening Design Considerations
The project structure is complex, the volume is huge, so the deepening of the design work is very
important. In the process of deepening the design must be considered comprehensively, to lay a good
situation for the subsequent construction. It is recommended that the following factors be taken into
consideration in the deepening design process.

6.1. Pre-Adjustment Value for Structural Construction
Structural pre-adjustment during construction is always a dynamic adjustment process, and part of the
structural pre-adjustment (i.e., production of pre-adjustment values) will be performed during the
construction detailing and component fabrication phases to bring the structural stage completion state
in line with the initial bit shape required during structural analysis [7].

6.2. Methods and Construction Measures for Steel Structure Installation
According to the lifting equipment selection and installation method to carry out reasonable division
(sub-section) [8]. Tower crane installation, climbing required additional connection plate. Component
lifting required for lifting lugs, temporary connection plate, temporary deformation reinforcement
structure, etc. Reasonable node form, welding seam form, etc. is in line with the site installation
conditions. Lifting temporary safety measures required to increase the connection plate, bolt holes, etc.

6.3. Interface Measures with Civil Structure Construction
Rebar splicers required for civil engineering; eyelets to pass through rebar; bolts not easily welded at
the site; connections that may be required to fix formwork; holes designed for grouting of steel column
slabs; additional steel supports (both permanent and temporary) required for concrete construction of
the floor slab.

6.4. Needs of Electromechanical Disciplines
Electromechanical pipelines through the components of the holes and their openings for reinforcement
measures; need to preset the connection; electromechanical equipment base to be connected to the
steel structure plate; equipment lifting required for temporary connection with the steel structure plate;
elevator system and the steel structure of the connection, fixed plate, etc.
6.5. Demands for Curtain Wall Systems and Decorative Professions

Curtain wall system and decorative work to steel structure connections, fixing panels, holes, etc. [9] which is limited to dimensional accuracy by the construction accuracy of steel structure fabrication and installation of the part.

6.6. Requirements for Other Construction Measures

Connecting plates of construction elevator and steel structure; plates of concrete pump pipe connected to steel structure; plates of unloading platform connected to structure; plates of safety measures temporarily fixed to steel structure.

7. Conclusion

Today, the steel structure deepening has been out of the traditional concept of sketching proofs [10]. And composite drawing technology is constantly integrated into the field of deepening design. Whether it is just a surface model provided by the superstructure, or a few nodes and samples of all the positioning layout design sketches concerning the architectural drawings, deepening design can always use the relevant software, meanwhile, in-depth non-steel structure professional and architectural or electromechanical communication, actively develop ideas and play a role to carry a connecting link between the preceding and the following.

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