

Deepening Design Technology of Super High-rise steel Structure

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Abstract: In view of the difficulties in deepening design of super-high-rise steel structures, we try to use Tekla Structures 3D intelligent steel structure simulation design software to carry out the corresponding deepening design, and verify the implementation effect of the deepening design with engineering practice, providing reference and reference for similar projects. The research shows that Tekla Structures is a very efficient and convenient software for steel structure deepening design; The connection nodes between giant columns and trusses should be divided in sections according to the principle of dividing along the section and along the column height, and reasonable lifting lug plates and studs for site use should be set; For hot-rolled steel plate composite floor slab, full-length reinforcing plates with the same thickness as the steel plate shall be set longitudinally on both sides of the splice weld of the adjacent unit steel plate; The thick plate welding shall be subject to process review in advance.

Keywords: Super high-rise steel structure, Giant column, Giant support, Node deepening, Steel plate wall, Ring truss.

1. Introduction

After the construction drawing design of super high-rise steel structure is completed, it is usually necessary to continue to deepen the design according to the design depth of the construction drawing, structural system characteristics, manufacturing process, transportation and installation conditions, etc. After the deepening drawings are provided to the fabrication plant, the fabrication plant processes and manufactures through leveling, cutting, assembly, welding, painting and other processes, and finally forms the steel components required for the construction project [1,2].

The component types of super-high-rise steel structures usually include H-shaped components, round tube components, box-shaped components and special-shaped and giant components [3]. The deepening and fabrication of these components is an important link in the construction of super-high-rise steel structures. The design of component segmentation and joint mode in the deepening design stage will directly affect the construction quality of super-high-rise buildings [4,5].

This paper discusses the detailed design of steel structure with an example of steel frame in a super high-rise building project of concrete core tube+steel frame for reference of similar projects.

2. Research Content

Through the Tekla-Structures 3D intelligent steel structure simulation design software, the real model integration fitting deepening technology can effectively solve the problems such as the structural treatment of giant column and truss connection joints, the steel plate wall segmentation and structural treatment, the truss joint structural treatment, the hot rolled steel plate composite floor structural treatment, and the deep structural treatment of thick plate welding. The main research contents include construction process simulation and analysis technology, structural optimization technology, deepening technology of giant columns and giant supports, node deepening technology, steel plate wall deepening

technology, and ring truss deepening technology.

Based on the design institute's construction drawings, calculation sheets and other relevant data (including bidding documents, supplementary documents for answering questions, technical requirements, factory manufacturing conditions, transportation conditions, site assembly and installation plans, design zoning and construction conditions, etc.), and relying on professional software platforms, establish three-dimensional solid models, carry out construction process simulation analysis, carry out construction process safety check, calculate node coordinate positioning adjustment values, The process of generating structural installation layout drawing, component and component blanking drawing and report list. As a bridge connecting design and construction, the deepening design of steel structure is based on coordination with other disciplines, and plays an important role in the smooth progress of construction and the realization of design intent.

3. Key Technologies

3.1. Construction process simulation analysis technology

During the construction of super-high-rise steel structures, there are problems between vertical compression deformation and difficulty in measuring accuracy control (such as cross grid outer frame). These problems can be solved by setting preset values for compression and arch camber, outputting structural coordinates, etc. during the deepening design.

3.2. Structural optimization technology

The steel structure is closely related to other disciplines such as civil engineering, electromechanical equipment, curtain wall, etc. When there is a conflict between the structural design and site construction or the structural design of some nodes is unknown, it is necessary to optimize the components, nodes, and even the structural form and steel consumption.

3.3. Deepening technology of giant columns and supports

The deepening of giant columns and giant supports is the key point of the deepening design of super high-rise steel structures, and plays a decisive role in the implementation of the whole project. Giant columns and supports usually have the following characteristics:

(1) Large section size, thick plate and heavy weight

The one-way length of the steel structure giant column section is generally greater than 2m, the plate thickness is generally greater than 50mm, and the reinforcement layer can reach more than 100mm. Due to the large section and super-thick plate, the weight of the giant column per unit length is large, up to tens of tons. For example, in the Guangzhou East Tower project, the maximum length of the composite section of the giant column is about 11m, the maximum plate thickness is 170mm, and the maximum weight per unit length is 11.28t.

(2) Multiple docking nodes

In addition to butting with the surrounding steel beams, upper and lower steel columns, the giant columns usually have butt joints with outrigger trusses and ring trusses at the reinforcing layer, as shown in Figure 1, up to more than ten at most.

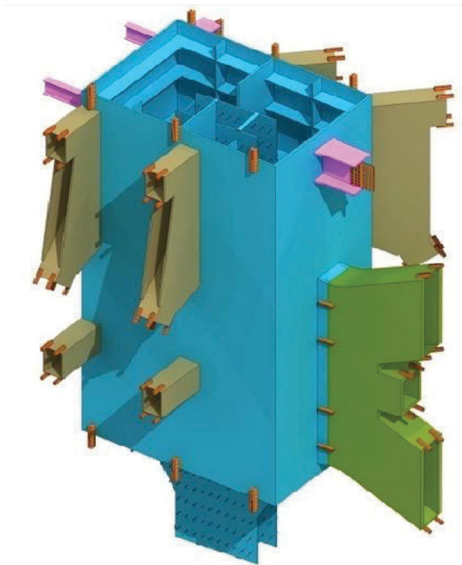


Figure 1. Schematic diagram of docking nodes

(3) Welding is difficult

During the welding of giant columns, in addition to the great difficulty in the quality control of thick plate welding, due to the complex setting of internal partitions of giant columns, the large connection area with concrete, and the large number of studs, the welding operators and equipment have brought many inconveniences. In view of these characteristics of super high-rise giant columns, to ensure the smooth progress of factory fabrication and on-site installation, the following items should be paid attention to when deepening the design of giant columns.

Reasonable segmentation can not only ensure the structure hoisting, but also reduce the deformation of components, reduce the welding difficulty and ensure the welding quality. Segmentation of giant columns shall meet the requirements of component transportation and lifting of on-site equipment. When the transportation width of giant columns is not more

than 4.5 meters, the section can be divided along the section. When it is greater than 4.5 meters, due to the size of the transport vehicle and the relevant requirements of road transportation, the giant column section shall be divided along the section and height direction, such as the Guangzhou East Tower project, the giant column section along the section, fully considering the transportation safety. When sectioning, reduce the site weld and vertical weld as much as possible to avoid overhead welding and weld crossing. To avoid overlapping of welds, steel plates at some positions can be merged and extended.

(4) Reasonable groove and weld form

In addition to butting with the surrounding steel beams, upper and lower steel columns, the giant columns usually have butt joints with outrigger trusses and ring trusses at the reinforcing layer, as shown in Figure 1, up to more than ten at most.

During the welding of components, the unreasonable groove design often leads to difficulties in operation, large welding deformation, low efficiency and large cost. In order to ensure the orderly production of components, reasonable weld form and groove form must be set during the deepening design.

When designing the welding groove, the factors such as angle, gap and blunt edge shall be reasonably considered to ensure that there is enough space between the electrode and the groove surface to facilitate the transition of the deposited metal, and to avoid incomplete fusion or slag inclusion; Ensure that the electrode arc can reach the bottom of the groove to avoid insufficient penetration depth; Ensure that the back of the root weld bead is not burned through, and promote better fusion and penetration of the weld.

The design of welding groove shall comprehensively consider the factors that are conducive to the welding quality, the difficulty of groove processing and welding, the use of welding materials, welding deformation, etc., to ensure low consumption, high efficiency, economy and applicability.

The shape and size of the welding groove shall be designed with full consideration of the welding equipment and the skill level of the welder to make the welding groove more targeted and universal.

The shape and size of all welding grooves shall be determined according to the welding procedure qualification results. To avoid stress concentration, the end of the rod and the hollow inflection point of the diaphragm can be filleted.

The butt joint of thick plate and thin plate shall be sloped according to the requirements of the specification. At the same time, in order to avoid the deformation of the end of the huge column in the box, the process partition can be set at the end. The opening of site welding "manhole" is a key point to be considered during the deepening of giant columns. Due to the complex section structure of giant columns, small spacing between corbel gusset plates, and many diaphragms, the position of "manhole" must be reasonably set to ensure that each weld seam has good welding space when the upper and lower columns are butted. At the same time, the opening size should be controlled between 500 mm and 800 mm, taking into account the construction cost and site workload and other factors.

The inner wall of the giant column shall be equipped with reasonable studs. The welding space shall be taken into account when modeling the studs. The spacing of the studs that are close to the plate or just arranged in the hole and weld position shall be adjusted or canceled.

3.4. Node deepening technology

The joint forms of super-high-rise steel structure mainly include: column base joint, support joint, column column joint, beam column joint, beam beam joint, truss joint, etc. The deepening main contents include the joint weld strength check calculation not specified in the drawing, bolt group check calculation, on-site splicing joint connection calculation, complex node space lofting, etc.

3.5. Deepening technology of steel plate wall

Steel plate wall is increasingly widely used in super high-rise buildings. At present, composite steel plate wall is mainly used in China. Composite steel plate wall is divided into single-layer steel plate wall and multi-layer steel plate wall. Among them, the single-layer steel plate wall panel has a large surface, the thickness of the steel plate is usually 20 mm - 80 mm, and the steel plate is often set with relatively dense studs, which is very easy to produce deformation during production. In order to reduce the deformation of the steel plate wall, the following measures can be taken during the deepening design:

(1) On the premise of meeting the requirements of transportation and installation, the component manufacturing unit shall be divided according to the principle of reducing factory welds and on-site vertical welds. When welding connection is adopted, the steel plate wall should not be too high in the height direction. For example, the section height of the Guangzhou East Tower project is about 3.3 meters, and the height stage can be divided into 20 lifting units at most, and the maximum length of the lifting unit is 13 meters.

(2) The thickness of steel plate wall is relatively thin, and there are many studs on both sides. When deepening the design, necessary stiffening plates shall be set to prevent the fabrication deformation, as shown in Figure 2.

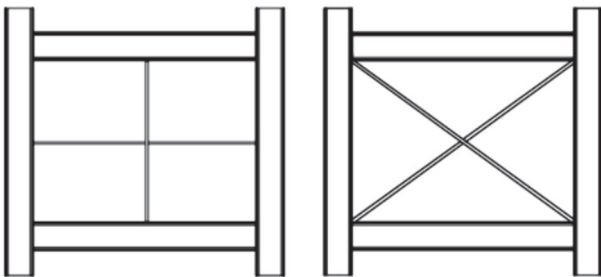


Figure 2. Schematic diagram of steel plate wall with stiffening rib

(3) Reinforce the reasonable holes reserved in the mechanical and electrical equipment drawings, such as air conditioning reserved holes, equipment holes, etc.

(4) The installation and construction scheme of the core cylinder steel plate wall and climbing formwork frame shall be fully considered, and reasonable holes for construction measures shall be set on the steel plate, such as steel formwork tie hole, formwork installation positioning hole, etc.

3.6. Deepening technology of ring truss

The ring truss is set at the structural reinforcement layer, and its height is usually 2 structural layers or more. Due to the importance of its structure, the steel plate thickness at the reinforcement layer is large (up to 100 mm and more). The following items shall be paid attention to when deepening the design.

Segmentation shall meet the requirements of component transportation and equipment lifting capacity. Generally, the ring truss is disconnected at the connection between the web and the upper and lower chords, and the corbel node is set at the intersection of the web to avoid overlapping of the intersecting welds of multiple members, and at the same time to ensure that the center of gravity of the members converge at a point at the node to avoid eccentricity. When it is not convenient to weld the butt joint on site, the welding hand hole can be set.

4. Application Experience Summary

Combined with this project, excellent practices and experience that can be used for reference by other projects include:

(1) Tekla-Structures software deepening

Tekla Structures is a 3D intelligent steel structure simulation design software. Its unique multi-user synchronous operation function creates a new way of information management and real-time collaboration. Users can build a complete steel structure model in the same virtual space at the same time. The model contains not only the geometric dimensions of parts and components, but also material specifications, sections, materials, numbers, positioning, user comments and other information. The operator can continuously rotate and view any component in the model from different perspectives, and can intuitively review the spatial logical relationship of each member in the model. When creating a model, you can create auxiliary points in the 3D view and input members, or you can build them in the plan view. Tekla Structures contains a variety of common nodes, which is very convenient when creating nodes. Just click a certain type of node, fill in the parameters, and then select the primary and secondary components in turn. You can query all manufacturing and installation information at any time, and check the collision relationship of the selected components. It can generate the required drawing and report list according to the model. All information is stored in the database of the model for calling at any time. When the design needs to be changed, only the model needs to be changed, and other data will be changed accordingly.

(2) Structural treatment of connection joints between giant columns and trusses

According to the layout of tower crane and site sections, the division of giant column component units shall be verified to ensure that the sections meet the requirements of transportation and lifting, as well as the requirements of structural stress, structure and welding. The principle of section division and column height division shall be adopted for the sections, so as to minimize site welds and vertical welds and avoid overhead welding. Single component unit is controlled at $16.8\text{m} \times 3.5\text{m} \times 5.6\text{m}$ (length \times wide \times High).

Set reasonable lifting lug plate for site use; Reasonably handle the butt joint transition of thin and thick plates to minimize the weld crossing; When the corbel extends into the giant column, the factory assembly process shall be carefully considered during modeling to ensure the welding space.

The opening and reservation of "trap" for site welding is a key point to be considered during the modeling of giant columns. Because of the complex section structure of giant columns, the spacing between bracket gusset plates is small, there are many diaphragms, and many diaphragms need to be welded on site. During the modeling, the site installation sequence and construction process should be clearly defined,

and reasonable welding manholes should be set to ensure that each weld can be well welded when the upper and lower columns are butted.

Set reasonable studs on the inner wall of the giant column, and consider the welding space when modeling the studs. Adjust the spacing or cancel the studs close to the plate or arranged at the hole and plate position; Set reasonable grouting holes and air holes on the partition; In the process of modeling, the assembly process of each giant column component should be carefully considered to ensure that the groove opening is reasonable, and the structure of the welding part of the thick plate meets the welding requirements, to prevent lamellar tearing during the welding of the thick plate, and to meet the welding space.

(3) Structural treatment of hot-rolled steel plate composite floor

The hot-rolled steel plate laid on the truss floor shall be deepened from the following aspects.

Divide reasonable steel plate units according to the layout of steel beams, and try to control the size of components at 3.5m wide \times Within 2.8m in height, in order to ensure that the bearing capacity of the steel plate meets the design requirements under the action of variable load during the installation phase, the steel plate is longitudinally stiffened with L shaped stiffening plates with an interval of 500mm or 1000mm.

The floor steel plate needs to be welded into a whole piece at the construction site. In order to prevent the deformation of the single steel plate in the longitudinal direction during the on-site welding, the full-length reinforcing plate with the same thickness as the steel plate is set longitudinally at the two sides of the joint weld of the adjacent unit steel plate; Plug weld connection with the main beam, the upper chord of the truss and the secondary beam. According to the thickness of the floor steel plate and the requirements of the welding process, different slot sizes are selected for different plate thicknesses. When the steel plate thickness is 8mm and 10mm, the long hole is 18mm \times 60 mm, when the steel plate thickness is 15 mm and 20 mm, the long hole is 26 mm \times 75 mm.

The steel plate and the side beam are mainly connected by fillet welding on site, and the outer frame column, giant column, this frame column, giant brace are connected by lap plate welding. The longitudinal and transverse splices of steel plates are connected by full penetration butt welding, and the weld quality grade is Grade I.

(4) Structural treatment of thick plate welding

The biggest feature of the plate in the super high-rise project is that there are a large number of high quality and high performance thick plates. The weld design and the design of welding construction measures based on the consideration of thick plates are a key point of the deepening design.

According to the material characteristics of thick plates, the following aspects should be considered in the deepening design: before deepening, the group should focus on the analysis of the connection nodes between giant columns and trusses, the connection nodes between outrigger trusses and core tubes, steel plate walls, corner V braces, giant columns, and tower top cast steel nodes, and carry out process review on each connection part and site section points; Determine the welding construction measures of each connecting part, and conduct process assessment for key parts; The specific weld

form, groove size and direction of each part shall be designed.

5. Engineering Application Effect

Through the Tekla Structures 3D intelligent steel structure simulation design software, the real model integration fitting deepening technology was successfully applied to a project, which successfully solved the problems such as the structural treatment of the connection joints between giant columns and trusses, the steel plate wall segmentation and structural treatment, the truss joint structural treatment, the hot-rolled steel plate composite floor structural treatment, the deep structural treatment of thick plate welding, etc., accelerated the deepening of the drawing, and solved the subsequent processing and manufacturing A series of problems, such as on-site installation, have provided a favorable guarantee for the quality and quantity of the project.

6. Conclusion

In view of the difficulties in deepening design of super-high-rise steel structures, we try to use Tekla Structures 3D intelligent steel structure simulation design software to carry out the corresponding deepening design, and verify the implementation effect of the deepening design with engineering practice, providing reference and reference for similar projects. The main conclusions are as follows:

(1) Tekla Structures is a highly efficient and convenient software for deepening design of steel structures.

(2) The connection nodes of giant columns and trusses should be divided in sections according to the principle of dividing along the section and along the column height, and reasonable lifting lug plates and studs for site use should be set.

(3) For hot-rolled steel plate composite floor slab, full-length stiffeners with the same thickness as the steel plate shall be set longitudinally on both sides of the splice weld of the adjacent unit steel plate.

(4) The thick plate welding shall be subject to process review in advance.

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