Analysis of Key Points of Steel Structure Construction Technology in Film Engineering Projects

M. Alashoub Turki Sulaiman and Chunyu Liang

Abstract According to the soil conditions of high-rise buildings and foundation pits of steel structure projects, the technical analysis of steel structure projects is carried out. Because the project is located at an earthquake-resistant fortification intensity of 8 degrees, and the design basic seismic acceleration value is 0.30 g, the high-rise building adopts steel structure structure to ensure the performance of seismic performance, safety level, bearing capacity and other aspects. This paper introduces the steel structure construction technology in detail from the five links of steel structure deepening, construction sequence, component manufacturing process, fire prevention and anti-corrosion, and component hoisting, and analyzes the construction process and the key points of quality control in construction. Practice shows that the application effect of this technology is good and the economy is reasonable.

Keyword Steel structure; High-rise building; Quality control

1 Project Overview

This project has three workshop buildings (1#, 2#, 3#) and one supporting comprehensive service building (4#). Among them, Buildings 1# and 2# are Class E high-rise workshops with 12 floors above ground and 2 floors underground, their building height is 95.60 m; Building 3# is a Class E high-rise factory building, with 8 floors above ground and 2 floors underground, whose height is 65.60 m. The standard floor height of the building is 7.8 m, the land area is 30997.27m^2, the total construction area is 149041.11m^2 (see Fig. 1), and the building's fire rating is Class 1.

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Fig. 1 Caption of a typical figure

1.1 Geological Conditions of Foundation Pit

The survey report found that, within the drilling depth range, based on the field characteristics of the stratum and the results of the indoor geotechnical test, the strata of the proposed site from top to bottom are plain fill, Quaternary Holocene flushing, The alluvial layer, Quaternary residual layer and Yan shanian granite.

1.2 Ground Motion Parameters of the Project

According to the relevant provisions of Appendix A.0.19 of "Code for Seismic Design of Buildings" (GB50011-2010) (2016 Edition) and "China Earthquake Parameter Zoning Map" (GB18306-2015), the seismic fortification intensity of this site is 8 degrees, and The acceleration value of the basic seismic design is 0.30 g, and the design earthquake is grouped into the first group.

1.3 Site Soil Type

According to the name and properties of the rock and soil in the site, combined with local experience, the estimated shear wave velocity experience value of each layer is shown in Table 1:

Table 1 Estimated value of shear wave velocity for each soil layer

Strata	Shear wave velocity empirical value/m.s^{-1}	Type of soil
Plain fill	135	Soft soil
Silty clay	210	Medium soft soil
Sandy clay soil	260	Medium hard soil
Strongly weathered granite	550	Soft rock
Medium weathered granite	850	Hard rock

According to the empirical values in the table, three borehole numbers are selected for shear wave velocity estimation, and the equivalent shear wave velocity estimation results are 179.4, 210.7 and 218.4 m/s, ranging from 150 to 250 m/s. According to the nearby data and the survey results, the thickness of the covering layer is between 3 and 50 m in this site, and the construction site category is Class II.

2 Technical Analysis of Steel Structure

2.1 Basic Idea

Compared with traditional buildings, steel structure houses can better meet the requirements of flexible separation of large bays in buildings, and can improve the area utilization rate by reducing the cross-sectional area of columns and using lightweight wall panels, the use of steel structure systems in residential buildings can fully has good ductility, strong plastic deformation ability, and excellent seismic and wind resistance, especially in the event of earthquakes and typhoons, which can avoid the collapse of buildings.

In view of the characteristics of high seismic performance and flexible space of this project, the use of steel structure frame is particularly prominent. According to the actual construction conditions on site, the steel structure construction technology is planned to be selected.

2.2 Basic Principles

(1) Reasonable selection of materials, structural plans and structural measures to meet the strength, stability and stiffness requirements of the structure during transportation, installation and use.

(2) Corresponding fire protection measures should be taken according to the fire resistance level. The heat resistance of the steel structure is good, but the fire resistance performance is poor. Steel is heat-resistant but not high-temperature resistant. As the temperature increases, the strength decreases, and structural safety problems are prone to occur.
(3) Before hoisting, the strength and stability of the steel structure should be checked, and the hoisting point should be defined to prevent the deformation of the component due to uneven stress.
(4) Welding is the most important step in construction, which is very important for every construction worker. If the welding is not in place, it is difficult to ensure the safety of the project, so the welding quality is particularly critical.

3 Analysis of Key Points of Installation and Construction Technology

3.1 The Deepening of the Steel Component Assembly Plan and the Key Points of Assembly Construction

The deepening assembly scheme of steel columns and steel beams

The floor height of this project is high, and the total amount of steel structure is 20,000 tons. The key work of the steel structure deepening joint design is to solve the relationship between the steel structure and the concrete structure, and the operability of complex joints in the process of factory processing and on-site welding. The depth of the detailed design node diagram can not only meet the requirements of steel procurement, but also meet the requirements of processing drawing design, and do a good job in the preliminary design work such as holes for civil reinforcement, holes for mechanical and electrical equipment, and curtain wall connectors [1, 2].

The deepening assembly scheme of steel columns and steel beams

(1) The structural engineering is absolutely safe and reliable;
(2) Grasp the intention and structural characteristics of the original structural design;
(3) Coordinate with other professional designs (outdoor curtain wall engineering, interior decoration engineering, mechanical and electrical engineering, etc.);
(4) The steel structure design should be deepened and optimized scientifically and rationally to fully reflect its economic rationality;
(5) The design drawings must meet the requirements of factory processing and on-site installation;
(6) Strictly follow the design procedures and cooperate closely with the owner and the design institute to ensure the smooth progress of the design work.

Key points of steel structure deepening

(1) Improve the structure of the components and determine the size of the gusset plate;
(2) Calculation of welded joints or bolted joints to determine the length of the welds of certain components and the dimensions of the connecting plates;
(3) Determine the form of connecting nodes in the component;
(4) Considering the transportation and installation capabilities of the transportation department and the installation department, determine the segments of the components.

3.2 Optimizing the Construction Sequence

The steel structure construction mostly adopts the construction technology of segmented ground assembly and segmented hoisting inside and outside the site. In view of the characteristics of this project, such as a high degree of multi-professional interleaving and collaboration, and a small site, based on comprehensive consideration of the site conditions, The general construction sequence is the first underground and then the above ground; structure first, then enclosure; first steel structure and then civil construction.

3.3 Main Components Manufacturing Process and Quality Control Points

The sequence of steel structure welding is pre-welding inspection → preheating and rust removal → installation of welding pad and arc strike plate → welding → inspection. The steel structure welding quality of this project is high, and all of them are required to be full penetration welds. The main welding types are on-site butt welding, assembly welding and high-altitude welding. According to the characteristics of long structural welds and thick plate thickness, CO2 gas protection semi-automatic welding is adopted on site. Welding process combined with solid wire weld fill. In order to ensure the welding quality of the project, in strict accordance with the relevant provisions of GB 50661-2011 "Steel Structure Welding Specification" and GB 50205-2020 "Steel Structure Engineering Construction Quality Acceptance Specification" [3], the welding process plan and the inspection and evaluation are formulated.

Welding process flow

For projects with large steel structures and complex joints, strict welding procedures should be formulated to ensure the quality of on-site welding. Combined with the welding process on the construction site, the welding process formulated in this project is shown in Fig. 2.

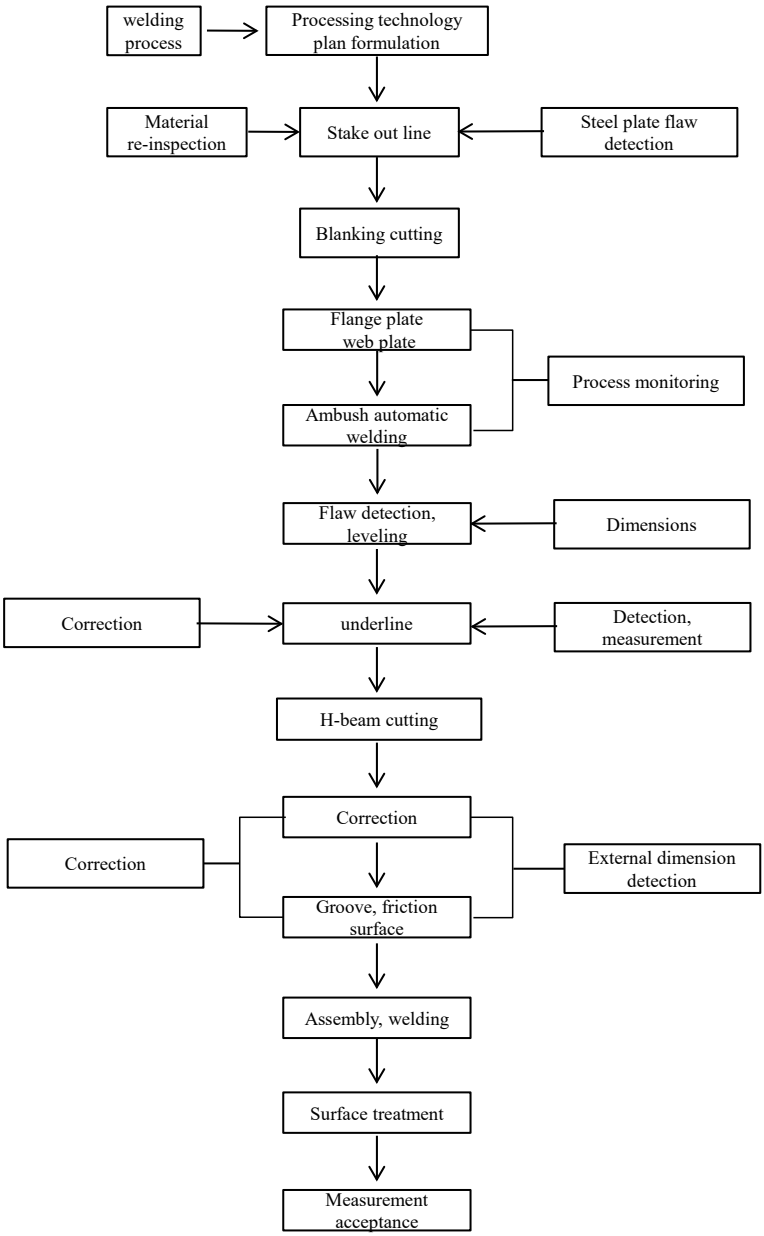

Fig. 2 The welding process formulated

Preparation before welding

Before welding, the welding process document should be prepared according to the welding process evaluation results. The assembly of the welding parts, the surface cleaning quality and the position deviation of the components should be checked. The welding procedure document mainly includes the following contents [4]:

(1) Determine the welding method of different components;
(2) Clarify the information such as the grade and specification of the welding base metal used in the project;
(3) Determine the form of welded joints and grooves;
(4) Give the welding tolerance requirements;
(5) Clarify the relevant technical requirements of each process (fixtures, backing plates, current, voltage, etc.) and process parameters;
(6) Determine the quality inspection standards.

Key points of welding quality inspection

All outer frame beam and column connections and component splicing welds of this project are fully penetrated welds, which is primary welds. The main inspection points are as follows:

(1) Check the weld surface for defects such as cracks, slag inclusions, weld penetrations, arc craters and pores.
(2) According to the relevant national standards, check whether there are defects in welds, joints, etc. that do not meet the requirements of defect classification.
(3) After completing the visual inspection of the weld, the flaw detection should be carried out. For different weld types and thicknesses, different methods such as ultrasonic flaw detection, magnetic particle flaw detection or color flaw detection are used.
(4) When local flaw detection finds that there are permissible defects in the weld, the flaw detection length shall be increased by not less than 10% of the length of the weld at its extension. If there are still permissible flaws, 100% flaw detection shall be carried out.

Measurement control points

(1) The positioning measurement of steel structure construction should first establish a reliable plane control network and elevation control network.
(2) For the positioning of inclined steel columns, a precise three-dimensional control network must be established, and the preset accuracy is calculated according to the requirements of the steel structure measurement progress.
(3) When measuring the ground assembly process, control points should be set up in each assembly site first, and a local plane and elevation control network should be established to provide a benchmark for accurate positioning of the tire frame and subsequent position re-measurement.
(4) When performing error detection and correction on the relative position of each component in the structure [5].

3.4 Anti-corrosion and Fire-Proof Coating Control

Main points of anti-corrosion coating technology

(1) All steel components shall be subjected to surface sandblasting (shot) derusting treatment before painting, and the derusting grade shall be Sa2.5.
(2) Airless spraying is required for the surface anticorrosion of all components.
(3) The construction environment temperature is 5 ~ 38°C, and the relative humidity is 30 ~ 85%.
(4) There are generally oxide scale and rust on the surface of ferrous metals, which must be removed before painting, otherwise economic losses will be caused.
(5) When the shot blasting and rust removal is completed, remove the dust and other debris on the surface of the metal coating.
(6) Spray primer. After shot blasting and rust removal, the primer must be sprayed within 6 h.
(7) Paste or oil-based pen to mark the component number on the painted surface or bare metal surface, and mark the installation direction of the component, which is convenient for on-site identification and installation.

Technical points of fire protection coating

(1) Steel columns, steel beams, steel supports, steel stairs, etc. should be protected by fire-resistant paint, and the type of fire-resistant paint should meet the requirements of architectural drawings.
(2) Fire retardant paint and steel structure anti-rust paint must be compatible and adaptable.
(3) After the construction of the fire-resistant and anti-corrosion coating is completed, the data such as the thickness and adhesion of the paint film should be tested.
(4) The fire retardant coating is applied by spraying to ensure that it does not fall off and is not hollow during normal use.
(5) The fire retardant coating should be able to maintain good durability under the action of wind speed and wind pressure generated by elevator operation in the elevator shaft.

3.5 Steel Structure Hoisting Scheme

Technical points of fire protection coating

The hoisting of components adopts the comprehensive construction technology of high-altitude hoisting of steel structure. The frame column adopts the vertical section hoisting technology; the truss adopts the factory section processing and aerial docking installation technology. When the floor structure is installed, the frame bay is used as a unit, and the installation is started in the order of the steel column first, then

Table 2 The statistics of the steel components of each building in this project

Standard floor components		Building 1#	Building 2#	Building 3#
Outer framesteel column	Qty/piece	35	43	32
	Weight/ton	400	330	200
Core tube steel column	Qty/piece	30	25	24
	Weight/ton	20	20	18
Steel beams	Qty/piece	187	261	258

the main beam and the secondary beam. After forming a stable frame, it gradually spreads to all sides. After the hoisting, the measurement and correction, the initial and final tightening of the high-strength bolts, and the welding should be carried out in time.

Technical points of fire protection coating

The film factory project is a pure steel structure. The statistics of the steel components of each building in this project are as follows (Table 2):

According to the component characteristics of the project's steel components, the largest component section, and the largest single-section weight of the steel column, the TC8039 tower crane (55-m arm length) is used, and the hoisting performance is as follows (Table 3):

Selection of sling wire rope and snap ring

In this project, the high-strength carbon steel wire rope commonly used in the hoisting project is selected, and the 6 × 37 wire rope is selected. If the force of the steel wire is uneven, the breaking force of the whole steel wire rope should be calculated as follows:

$$SP = \lambda \times \sum S_i \tag{1}$$

Table 3 The hoisting performance

Amplitude /m		3.5–18.85		20	23	25	28	30	33
Lifting capacity/t	Double rate	12.5							
	Quadruple	25		23.32	19.80	17.94	15.67	14.42	12.83
Amplitude/m		35	38	40	43	45	48	50	53
Lifting capacity/t	Double rate	12.5	11.87	11.19	10.29	9.76	9.05	8.63	8.05
	Quadruple	11.93	10.76	10.08	9.18	8.65	7.94	7.52	6.94
Amplitude /m		55							
Lifting capacity/t	Double rate	7.70							
	Quadruple	6.59							

In the formula: *SP*—the breaking force of the wire rope, kN;

ΣSi—the sum of the breaking force of the steel wire provided in the specification table of the steel wire rope, kN;

λ—Uneven reduction coefficient of steel wire twisting, for 6×37 rope, $\Psi = 0.82$.

The heaviest steel column in this project is about 12t, and four steel wire ropes are used for hoisting. Considering the most unfavorable situation, 2 steel wire ropes will bear the full weight. Considering the minimum tension calculation: $SP = \Psi \Sigma Si = 156 \times 0.82 \times 0.102 = 13.05 > 12$, which meets the requirements.

According to the relevant regulations of "Forged Shackles for General Lifting-D Shackles and Bow Shackles", 2 T, 3.25 T, 6.5 T, 8.5 T, 12 T and other shackles are mainly selected for this project, among which shackles below 3.25 T are used for hoisting lighter components such as steel beams, and shackles of 6.5 T above are used for hoisting heavier components such as outer frame columns, which meet the requirements.

4 Conclusion

Combining with the characteristics of the project, this paper makes a comprehensive study on the construction sequence, component assembly, hoisting, welding, welding inspection and control of anti-corrosion and fire-proof coating in the steel structure construction process for the project using reinforced concrete + steel structure frame structure system. The actual construction period of the project is 45d ahead of the planned construction period, and the economic benefits are obvious, which provides a reference for similar projects of high-rise buildings.

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