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Research on key technologies for construction of steel structures in ultra large span cold storage

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Abstract: Taking the 100,000-ton automatic cold storage construction project of Weizhou Investment Holding Co., Ltd. as an example, this thesis systematically analyzes the main difficulties in the construction of super-large-span steel plant in terms of material transportation and handling, large-size components lifting, joints handling and welding, foundation reinforcement, and puts forward corresponding solutions. It not only provides practical suggestions for solving the difficulties in the construction of super-large-span steel structure plant, but also has guiding significance for improving the construction quality and safety management level of the whole industry.

Keywords: Ultra large span; Cold storage steel structure; Construction technology.

1. Introduction

With the rapid development of modern industrialization, large-span steel plant is widely favored for its high space utilization rate and short construction period, and this kind of structure is usually applied in the fields of aviation, shipbuilding, large-scale warehousing centers and exhibition halls, etc. However, there are still many construction difficulties in the design and construction of large-span steel plant, including material handling and transportation, large-size components lifting, joints handling and welding, However, there are still many construction difficulties in the design and construction of large-span steel plant, including material handling and transportation, lifting of large components, joint handling and welding, foundation reinforcement, etc., which not only affect the construction progress and cost, but also concern the safety and stability of final structure. Therefore, this paper systematically analyzes the difficulties in the construction of super-large-span steel plant, discusses the specific problems in the actual project, and puts forward the corresponding solutions. [1-4].

2. Project Overview

Weifang Weizhou Investment Holding Co., Ltd. 100,000 tons of automated cold storage construction project is located in Weifang City, north of Beigong West Street, west of Nanxu Road. Planning and construction of 1 #, 2 #, 3 # a total of three automated cold storage and the corresponding outdoor ancillary works, cold storage attached to the construction of supporting workshops, offices and equipment rooms. The planning net land area is 42,296m2, and the total construction area is about 29,163m2. The cold storage has two floors above the ground, and the building height is 46.1m, in which the cold storage is mechanized automatic three-dimensional single-floor cold storage, and the single-floor steel rack structure; the design adopts high-strength steel to support the large-weight machinery and equipment, and the most important difficulties in the construction are the lifting of the extra-long steel beams and the accurate docking, as well as the problems of beam transportation and the site lifting in the process of the construction. After analysis, it was found that the main construction difficulties were the lifting and accurate docking of the extra-long steel beams, as well as the transportation of the beams during the construction process and the safety of lifting on site.

Fig.1 Rendering after completion

In order to solve the above problems, the project team adopted a segmental transportation assembly strategy, whereby each 30m-long steel girder was prefabricated into smaller steel girder segments, which were then welded on site. For lifting, two crawler cranes with a capacity of 120 tons were used, and computer simulations were used to ensure the optimization of each lifting step and path. In addition, a real-time monitoring system was installed at the construction site to monitor the quality of steel girder welding and the dynamic changes during the lifting process through high-definition cameras and sensors. Through the above program, the completion time of the whole lifting process was 15% shorter than expected, and no safety accidents occurred. [3-7]

3. Difficulties in the construction of super-large-span steel structure cold storage

3.1. Material handling and transportation

In the construction process of large-span steel cold storage, material handling and transportation is a significant difficulty. On the one hand, large-span steel structures usually require steel parts with large size and heavy weight, which puts higher requirements on the capacity of logistics handling equipment such as cranes and transportation vehicles. On the other hand, these large components require special spatial and technical support for storage and transfer to prevent damage or deformation of the material during transportation. Long-term open-air storage of steel can cause corrosion or other quality problems due to climatic conditions. Meanwhile, the long distances between the production locations of different components and the construction sites form a complex logistics chain, which increases the difficulty of scheduling as well as transportation costs.

3.2. Lifting of large components

Because of its huge volume and weight, large components have extremely high requirements on the performance of lifting equipment. The lifting precision of large components is very strict, and any small error may lead to improper installation of components, affecting the safety and stability of the whole structure. At the same time, large components in the lifting process by the wind, temperature and other natural conditions have a greater impact on how to stabilize the lifting of large components in a complex and changing environment is a major problem. The constraints of site construction environment such as narrow space and uneven ground also bring additional difficulties to the lifting operation.

3.3. Joint treatment and welding

In joint treatment, the joint design must meet the requirements of structural mechanics and ensure that the material properties are fully utilized. Since large-span steel structures are usually subjected to tremendous pressure, joint strength is crucial to the overall stability. Welding, as the main means of joining large steel components, not only needs to ensure the strength and toughness of the weld seam, but also needs to consider the heat affected zone during the welding process and its potential impact on material properties. On the construction site, high-quality welding requires the use of high-level process specifications and operational skills, while taking into account the impact of environmental factors such as temperature and humidity on the welding effect.

3.4. Foundation Reinforcement

Large-span steel cold rooms usually require higher load-bearing capacity for foundations due to their large space and coverage. The foundation must have sufficient bearing capacity to support the weight of the large-span steel cold storage, including the steel, roofing system and later use loads. In the construction process, the use of large mechanical equipment will cause instantaneous high load impact on the ground, so the foundation is required not only to have strength, but also good stability and a certain degree of seismic resistance. Foundation uniformity is also one of the factors affecting the overall structural safety. Uneven settlement will lead to deformation or even damage of large-span steel cold storage, which will eventually cause serious quality problems.

4. Large-span steel structure cold storage construction solutions

4.1. Optimize material handling and transportation solutions

In order to solve the difficulties of material handling and transportation in the construction of large-span steel cold storage, this paper puts forward a set of optimization solutions, including accurate material demand prediction, phase-by-phase supply strategy, and optimization of transportation management by using information technology. First of all, the combination of historical data analysis and computer simulation is used to predict material demand.

First, a combination of historical data analysis and computer simulation is used to forecast material demand. For example, by analyzing the actual consumption data of 10 similar projects in the past, a linear regression model was used to predict the material demand for each construction phase, and the prediction accuracy reached more than 95%. Secondly, we implemented a phased supply strategy, which categorizes

Secondly, it implements a phased supply strategy, dividing the supply of materials into three phases, namely, initial, intermediate and later phases, and adjusting the types and quantities of materials according to the actual needs at each phase to minimize the losses caused by the backlog of materials. For example, only 20% of the estimated total demand is supplied at the initial stage of welding materials, and the subsequent supply is dynamically adjusted according to the construction progress. Finally, the use of information technology to optimize transportation management, through the geographic information system (GIS) and radio frequency identification (RFID) technology, real-time tracking of the location and status of the materials, to ensure the accuracy and timeliness of the transport, for example, through the automatic recording of the materials out of the warehouse, in transit and on the site through the RFID tags, as well as the use of GIS to optimize the transport routes to reduce the cost of more than 5% of the cost and time of transport.

4.2. Innovative lifting scheme for large components

4.2.1. Lifting program design

In the design of lifting scheme, the focus is to ensure the safety and accurate positioning of the large-span steel structure. Firstly, for specific components such as beams and columns, mechanical analysis needs to be carried out according to their length, width and weight in order to determine the optimal location and number of lifting points. Secondly, choose suitable lifting equipment. Thirdly, a detailed lifting sequence and path planning is developed to avoid mutual collision of components during construction. For example, when lifting a component weighing 10 tons, it is necessary to reserve at least 1.5 times the safe load space, i.e., choose a safe working load of at least 15 tons. Considering the influence of wind speed on the lifting operation, the operation must be carried out under the condition that the wind speed is lower than 5m/s, and the real-time wind speed monitoring instrument is set up to suspend the operation in time when the wind speed is determined to be out of the safe range, and the stability coefficient during the subsequent calculation of the lifting construction (usually the stability coefficient should be not less than 1.3), which can be fulfilled by increasing the counterweight of the crane or adjusting the jib span. Finally, after the completion of the above steps, generate a detailed lifting plan, including the time schedule of each step, staffing, safety checklist and emergency contingency measures, while the lifting program simulation exercises to verify the feasibility of actual operation.

4.2.2. Selection of lifting equipment

First of all, when selecting lifting equipment, several key parameters such as the weight and volume of the components, lifting height and site space conditions must be considered. For example, for large steel beams weighing more than 50 tons, it is necessary to use crawler cranes with higher load-bearing capacity, while compact tire cranes are used in urban areas where space is limited. Secondly, the economics of the lifting equipment also needs to be considered, including rental costs, transportation costs and operating costs. In practice, the project manager needs to consider the specific situation (e.g., specifications of the lifted items, site conditions, etc.) and combine them with the costs to decide on the most appropriate lifting equipment. Finally, in order to optimize the lifting operation, simulation technology can be adopted to predict and verify the performance of the lifting equipment. By inputting the actual construction parameters into the calculation model, such as the position, angle, boom length and jib angle of the crane, the risks during the lifting process can be foreseen to a certain extent, and the lifting scheme can be adjusted accordingly.

4.3. Optimization of joint treatment and welding scheme

4.3.1. Welding material and technology selection

Welding material and technology selection is a key link in the construction of large-span steel cold storage, which directly affects the stability and durability of the structure. Welding materials should be selected with good mechanical properties, strong crack resistance and high depth of fusion of welding rod or wire. For example, the use of low-hydrogen type welding rod can effectively avoid hydrogen cracking in the weld. When selecting welding consumables, the chemical composition of the base material, post-weld treatment (e.g. heat treatment), as well as the intended working environment must also be taken into account. Also on-site testing is indispensable, e.g., the use of test pieces to evaluate the welding process parameters (e.g., current, voltage, wire feed speed, etc.) and results (e.g., weld bead shaping, mechanical property test results, etc.) of the selected material. Selection of automatic or semi-automatic welding techniques, such as submerged arc welding (SAW), gas shielded arc welding (GMAW) or flux-cored wire gas shielded arc welding (FCAW), can improve the welding efficiency and weld quality. Before welding, different welding materials and technologies need to be compared and analyzed to determine the most suitable combination of materials and technologies, and to develop an optimal welding program, which not only ensures the quality of the structure, but also improves the construction efficiency. [4-8]

4.3.2. Welding seam quality control

The quality control of welded joints is mainly realized by the following three methods: ① Ultrasonic Testing (UT): UT is a non-destructive testing technology, which can accurately locate defects inside the welded joints, such as porosity, inclusions or cracks, etc. UT has a high sensitivity, and can detect defects as small as 0.5mm in size, which is suitable for most of the inspection of welded joints. ②Radiation Testing (RT):RT is suitable for finding tiny defects deep in the weld, especially those areas that are difficult for UT to reach.RT can identify cracks and other types of defects over 0.2mm in size, but attention should be paid to protective measures to ensure safety when using RT. ③Magnetic particle inspection (MT): MT is mainly used to detect defects on the surface of the weld and near the surface, with high sensitivity, it can detect tiny cracks in the surface layer of 0.1mm, MT is easy to operate, low cost, and it is suitable for rapid inspection of large weld areas.

4.4. Adoption of Foundation Reinforcement Program

4.4.1. Foundation investigation

Before the construction of the large-span steel cold storage, accurate investigation of the foundation is the key to ensure the safety of the structure. Commonly used foundation investigation methods include drilling sampling and in-situ testing. Drill sampling obtains soil samples at different depths through rotary drilling to analyze the type, compactness and bearing capacity of the soil. For example, the penetration test quantifies soil compactness and expresses the data in terms of the number of blows per 30cm of penetration, i.e. the number of blows required to drop a standard hammer by 30cm. In addition, in-situ tests, such as the static contact test (CPT), can determine soil properties by measuring the resistance and lateral friction when penetrating the soil layer, with the output data typically being the resistance value and friction ratio. The detailed data obtained through foundation investigations provide a parametric basis for subsequent design, ensuring the scientific and engineering reliability of the foundation treatment program. [6-10]

4.4.2. Selection of reinforcement techniques

In the construction of large-span steel cold storage, foundations with poor soil quality or insufficient bearing capacity are usually reinforced by deep mixing, prestressing anchors and grouting. Among them, the deep mixing technology is applicable to a variety of soils, which can make the soil and cement become a homogeneous solidification through mixing, and its strength enhancement can be adjusted according to the actual needs. For example, increasing the cement mixing amount from 300kg/m3 to 400kg/m3 can increase the bearing capacity of foundation from 0.5MPa to 0.8MPa. Prestressing anchor reinforcement technology is suitable for rock and hard soil layer, which can effectively control the foundation displacement. For example, a prestressed anchor with a diameter of 32mm and a length of 15m can reach a maximum tensile force of 1500kN. Grouting technology is used to fill the voids and cracks and improve the overall compactness of the foundation, for example, applying mortar to a 10m-deep foundation, with a grouting volume of about 80L/m3, can significantly reduce the settlement at a later stage.

5. Conclusion

In order to successfully build a large-span steel cold storage, it is necessary to optimize the construction plan of large-span steel cold storage from the aspects of material handling and transportation, large-size components lifting, joints handling and welding, foundation reinforcement and so on. With the continuous innovation of technology and the application of new materials, in order to make the construction of large-span steel cold storage become more efficient and safe, it is necessary to continuously strengthen technological innovation and choose appropriate construction methods to improve the construction quality and safety level of the whole construction industry.

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