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Construction monitoring on the unloading process of steel roof for Guilin Liangjiang International Airport Terminal T2

Jindi Lin[1,*], *Yongbin* Wei[2], *and Maowei* Qiao[1]

[1]China State Construction Engineering Corporation, Beijing, China

Abstract. The main building of Guilin Liangjiang International Airport Terminal T2 adopts the steel reinforced concrete frame structure, the central roof uses the spatial solid web arch support and single-shell steel structural system with the largest supporting arch span of 120 meters, and the single-shell steel structural system is connected with the spatial solid web arch through diagonal bracing. The large-span space steel structure of the roof had a large building area, and more than 300 lattice columns were used for temporary support in construction. In the unloading process of steel structure, the deformation and stress of the structure changed greatly. Simulation for all construction steps of the main steel structure, the key steel members and structural locations with large deformations were found out, and the monitoring scheme of deformation and stress of steel structure were determined. The stress monitoring of steel structural was completed by the self-developed wireless stress monitoring system. The deformation monitoring points were automatically searched by the deformation robot, and the three-dimensional coordinates of each monitoring points were measured. The measured results were compared with the initial data, and the deformation of structure was obtained. In the whole process of stress and deformation monitoring, the early warning values were set according to structural analysis and material properties, which could help engineers to make decisions on the structural safety. After the smooth construction of the project, we would find that the monitoring system meted the monitoring requirement during the construction stage, and the result was an important evaluation index for the structure. The research methods used in this paper could be seen as useful reference for construction of similar projects.

1 Introduction

For some large-span steel structures, it is of great significance to monitor the stress during the construction stage [1-6]. The extension project of Guilin Liangjiang International Airport - T2 terminal, which is 377*355 metres in the size, is a U-shaped structure. The steel structure is composed of six parts: central roof steel structure, finger Gallery roof steel structure, supporting arch steel structure, boarding bridge steel structure, steel bridge and steel island steel structure. The total steel consumption is about 11,000 tons. Central roof steel structure is composed of supporting arch steel structure and roof steel structure, and it is the object of this monitoring. The supporting arch is a space curved solid-web steel structure arch. The centre area consists of seven pairs of relative oriented arc arches, which is 118,75,45,39 metres in the spans.

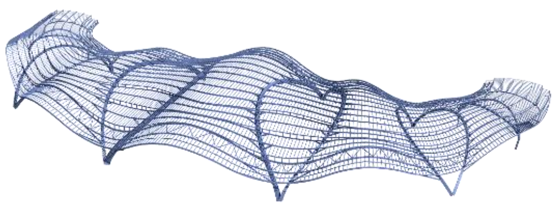


Fig. 1. Central roof steel structure.

Fig. 2. Supporting arch steel structure

2 Distributed unloading of steel structures

The unloading of the roof steel structure of the hall was carried out in three zones[7-9], as shown in Figure 3.

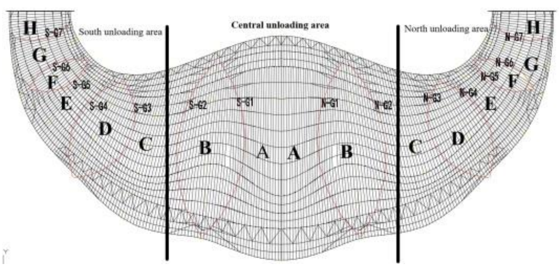


Fig. 3. Structural simulation model.

* Corresponding author: 277789443@qq.com

The first area is C-H in the north, the second area is C-H in the south, and the third area is A-B. The main components of the main steel structure are unloaded step by step after assembly. The unloading steps were as follows in Table 1.

Table 1. Unloading step

Step	Engineering condition
1	Temporary support for this structure
2	Demolition of temporary roof support in H
3	Demolition of temporary support in G7
4	Demolition of temporary roof support in G
5	Demolition of temporary support in G6
6	Demolition of temporary roof support in F
7	Demolition of temporary support in G5
8	Demolition of temporary roof support in E
9	Demolition of temporary support in G4
10	Demolition of temporary roof support in D
11	Demolition of temporary support in G3
12	Demolition of temporary roof support in C
13	Demolition of temporary support in G2
14	Demolition of temporary roof support in B
15	Demolition of temporary support in G1
16	Demolition of temporary roof support in A

The MIDAS GEN was used to simulate and analyse the structural changes in the construction process. Independent model was used in construction simulation calculation to analyse the change of structure in each construction stage. According to the results of simulation calculation, the key components of the structure were found and used as the focus of monitoring.

3 Wireless monitoring system

3.1. Wireless monitoring of strain system

The wireless monitoring of strain system was composed of sensor system, real-time acquisition system, real-time data transmission system, real-time data processing system, data storage and backup system, intelligent diagnosis and warning system, and so on. The sensor system has consisted of strain sensors and temperature sensors, which is used to monitor the response of the structure caused by construction and climate conditions.

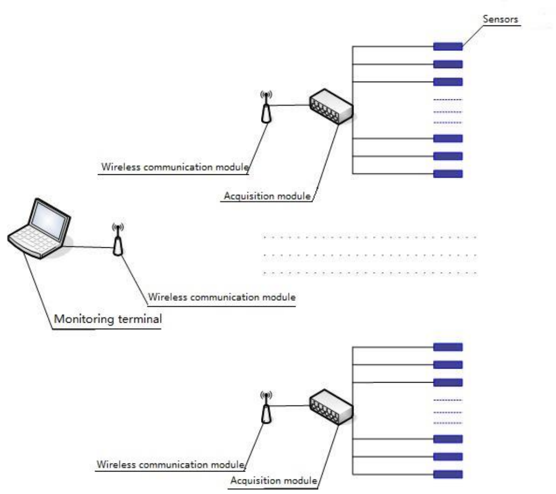


Fig. 4. Monitoring system

Due to the complexity of the construction site, the monitoring equipment adopts the wireless transmission mode, which is convenient to install the monitoring system in the construction site. The system also has data stability, high precision, reliability and durability, which can meet the requirements of long-term construction monitoring.

3.2 Deformation monitoring system

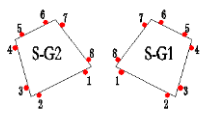
This project completed deformation monitoring by used Leica TS50. The accuracy of this instrument is 0.5 ", and the ranging accuracy is 0.6 mm + 1 ppm. So the instrument can meet the requirements of high precision measurement. The prisms were installed at the deflection observation points of each area of steel structure, and the position of the prisms were searched automatically by Leica TS50, and they were focused and measured automatically. The linear distance, horizontal angle and vertical angle of each measuring point was measured. The observation points were observed many times, and their average values were taken as deformation monitoring data. The deformation changes of each point were obtained by using data processing.

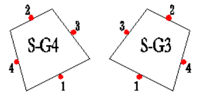
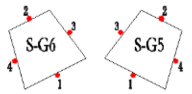
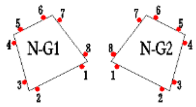
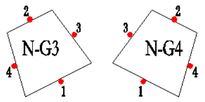
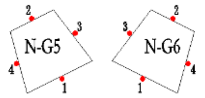
3.3 Plans of monitoring points

The strain measurement points should be located in the areas, where the strain changes obviously and the strain is complex. According to the results of MIDAS GEN simulation calculation, the monitoring scheme of this structure is shown in Figure 5 and Table 2. There were 64 monitoring points, each monitoring point was used to monitor strain and temperature. In this monitoring scheme, data transmission of the system should be as centralized as possible, and obey the principle of block centralization [10].

Fig. 5. Leica TS50.

Table 2. Installation of strain sensor

Position	Collector number	Installation diagram
S-G1、S-G2	935	

S-G3、S-G4	934	
S-G5、S-G6	941	
N-G1、N-G2	932	
N-G3、N-G4	942	
N-G5、N-G6	933	

According to the simulation results, the locations with large deformation were selected as the monitoring point of deformation, and the deformation monitoring of steel structure were carried out throughout the construction process. The deformation monitoring scheme is shown in Figure 6. There are 72 deformation monitoring points.

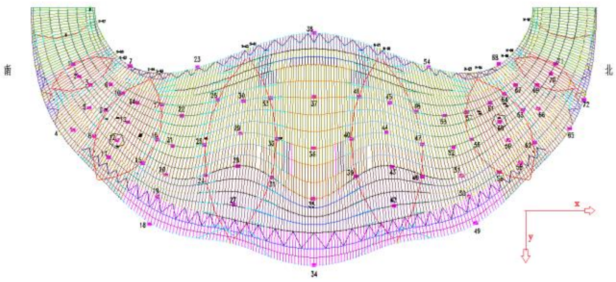


Fig. 6. Deformation monitoring pionts.

In order to avoid the inaccuracy of monitoring data caused by sensor installation, and then cause structural safety problems, the following details should be paid attention to in the process of sensor installation:

(1) The axis of vibrating wire sensor installed is parallel to the measurement direction;
(2) The sensor is firmly installed on the surface of steel structure;
(3) The sensor needs to be corrected for temperature compensation.

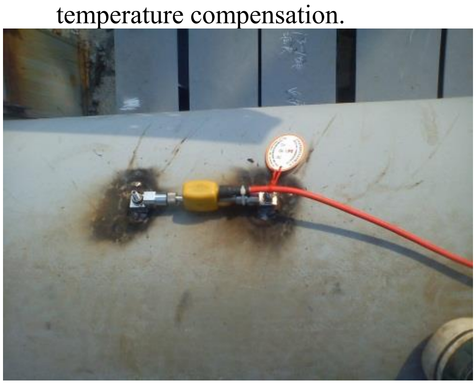


Fig. 7. Sensor installation.

3.4 The method of choosing initial strains value

The initial monitoring state of this project is the whole structures were welded and supported by temporary support. The state is defined as zero stress state. In fact, the steel components have stress due to their own weight at this moment, so it is necessary to get the initial strain and deformation value thorough the simulation by MIDAS GEN.

3.5 Monitoring results

From the beginning of unloading the temporary support, the initial value was collected, and the construction monitoring had been running for 1.5 months. During the whole construction monitoring period, the acquisition frequency of the monitoring system was adjusted according to the site construction conditions. For example, during the unloading construction period, the monitoring period was 5 minutes. The monitoring period changed to 30 minutes in the non-unloading period.

Monitoring data showed that most deformation monitoring points deformed downward and some of them deform upward during the whole unloading construction process. The maximum vertical deformation occurred at the 15th construction step of the monitoring point 44, whose deflection value was 97.45mm. In the X direction, the maximum deformation occurred at the 16th construction step of the monitoring point 39, whose deformation value was 31.5mm. In the Y direction, the maximum deformation occurred at the 16th construction step of the monitoring point 36, whose deformation value was 29.54mm. The trend of displacement change of each monitoring point in the whole construction process is basically the same as the simulation calculation structure. Taking the maximum vertical deformation monitoring point 44 as an example, the vertical deformation during the whole construction process is introduced, as shown in Figure 8. Due to the influence of temperature and part of roof construction, the monitoring point 44 was in the state of arch initiation before the 12th construction step. With the removal of temporary support, its deflection changed obviously, and the trend was basically consistent with the simulation results. The maximum axial compressive stress occurred at the monitoring point G5. According to the installation of field sensors, the average stress value of four sensors were taken as the strain values of the root of supporting arch on G5. The maximum stress was 22.6 MPa, which was less the simulated value. This was because the influence of temperature was neglected in the simulation calculation.

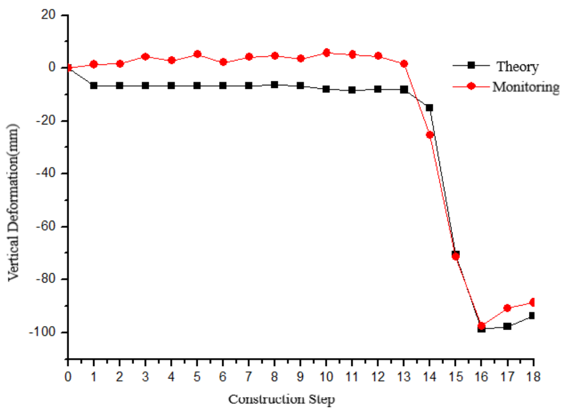


Fig. 8. Vertical deformation of point 44.

In summary, the stress of the structure in the construction stage is small. The stress value is far less than the strength yield value of steel. The deformation of the structure meets the requirements of construction checking. The maximum vertical deformation meets the control ratio of the roof structure within 1/350[4]. This construction monitoring has effectively guided the construction of steel structure, and it also ensured the safety of the structure construction process. In addition, it shown that the unloading scheme of this project was feasible.

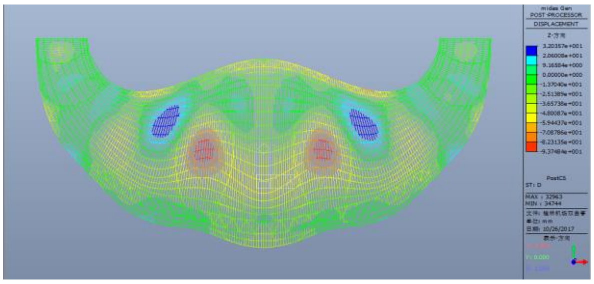


Fig. 9. Final deformation diagram

4 Conclusion

In this paper, the finite element simulation analysis and monitoring of unloading construction of steel roof in the center area of T2 terminal building of Guilin Liangjiang Airport. We can find the following conclusions.

(1)The monitoring system can complete the monitoring work in the complex construction site. And the system has the characteristics of good reliability, strong anti-interference ability and high sensitivity.

(2)For the construction monitoring of some complex steel structures, according to the simulation results, the key positions of the members are selected for the whole construction monitoring. This method can understand the internal force change and stress state of the structure in real time, and it can help engineer to ensure the safety of the whole structure.

(3)Temperature should be taken into account in the construction of complex steel structures. In the construction with large difference between day and night, it is necessary to consider the response of temperature stress.

(4)According to the results of simulation analysis and actual measurement, the unloading scheme of this project is feasible, and the selection of key points and key parts of monitoring is reasonable. This article can provide reference for the layout of measuring points of similar projects in the future.

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