Intelligent Construction Technology of Large-Span Steel Truss Arch Bridge Based on Intelligent Monitoring

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Abstract. To achieve digital monitoring and construction of steel truss arch bridges, developed intelligent monitoring system for main bridge stress, intelligent measurement system for main bridge linear, and automatic monitoring system for tower and anchors. And also developed an intelligent construction decision-making system for steel truss arch bridges by integrating these three systems. The use of digital intelligence construction assisted construction decision-making system has successfully monitored the stress, tower deviation, cable tension, and main bridge linear of steel truss bridge under various working conditions. The results show that the application of the system significantly improves monitoring efficiency and component installation accuracy, reduces environmental and human interference. When the monitoring value exceeds the limit value, a text message will be sent to remind the project leader, improving the safety of the entire construction period.

Keywords: Intelligent monitoring, large-span steel truss arch bridge, intelligent construction, measurement system

1 Introduction

In recent years, with the increase of urban vehicles, the driving environment in cities has become increasingly complex and there is often a need to cross rivers. The demand for beautiful bridges has also gradually increased. The large-span steel truss arch bridge has a beautiful appearance and combines the structural stress characteristics of truss and arch bridge, with strong integrity. Due to its minimal use of concrete materials, the bridge has a light overall weight, strong crossing capacity, and meets urban environmental protection needs, making it one of the commonly used bridge types in cities [1].

During the construction process, steel truss arch bridges have the characteristics of high precision requirements for multi-dimensional assembly. It is necessary to focus on controlling the arch ring line shape [2-3]. If excessive deviations are not corrected, as the arch ribs are assembled and the cantilever section becomes longer, the bridge structure will not only experience significant internal forces but also affect the final closure.

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Therefore, a complete system is needed to monitor the stress, linear, and tower displacement of the entire bridge. However, the existing steel truss arch bridges still rely mainly on manual monitoring, which has problems such as complex data processing, large information transmission deviations, and significant environmental impact factors [4-6].

This paper takes a double layered steel truss arch bridge with a main span of 408 meters as the research object, and uses Internet of Things technology and computer vision technology to develop an automated monitoring system for the construction tower and anchorage cable of large-span steel truss arch bridges, a bridge stress and linear monitoring system, and an intelligent construction auxiliary decision-making system. It will be applied to the full process automated construction monitoring of steel truss arch bridges, providing experience for subsequent related bridge construction.

2 Digital and Intelligent Construction of Steel Truss Arch Bridge

Through the intelligent stress monitoring system of the main bridge, the intelligent measurement system of the main bridge linear, the automatic monitoring system of the anchor tower and the anchor cable , after collecting the data of each system, the intelligent auxiliary system is comprehensively developed to form a digital intelligent construction auxiliary decision-making system for the long-span Truss arch bridge, The front-end of the system is a visual website used to display monitoring values. The front-end display sets corresponding bar charts, pie charts, curves, graphics, models, panoramas, and other content according to project requirements. The main technologies involved include web page technology (HTML, CSS, JS), AJAX technology, MySQL trans-mission technology, Pychart icon display technology, and UI design technology, as shown in Figure 1.

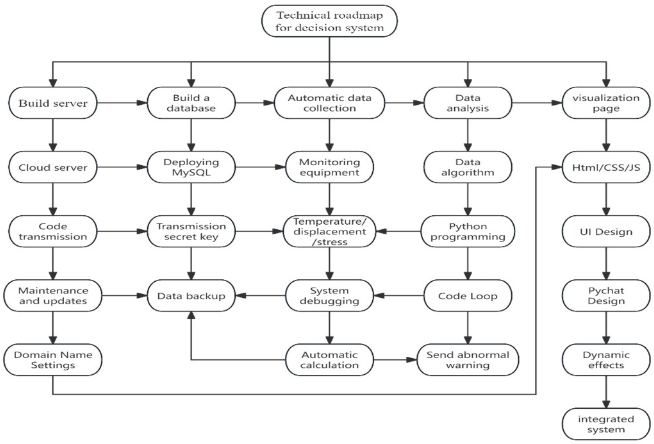

Fig. 1. Roadmap for decision system development technology

3 Project Profile

The length of Zhuzhou Qingshuitang Bridge is about 2.1km. The main bridge is a mid-supported steel truss arch bridge with a span arrangement of 100+408+100m. The upper deck is 31.0m wide, and the lower deck is a pedestrian walkway with a width of 10.5m. The steel main beam adopts a steel bridge deck UHPC composite structure in the mid span, and a steel beam concrete bridge deck composite structure in the side span. The horizontal tie bars on the bridge deck are made of hot extruded polyethylene high-strength steel wire cables. There are a total of 8 horizontal tie bars on the bridge deck, with 4 of them arranged on each truss, they are fixed on the top surface of the main longitudinal beam through brackets. As shown in Figure 2.

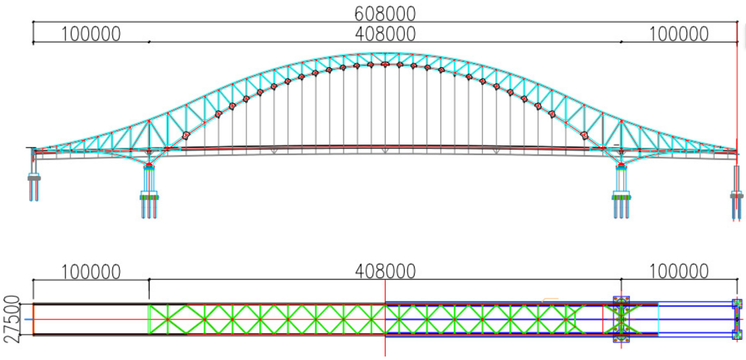

Fig. 2. Elevation and plan of bridge

4 Intelligent Monitoring of Large-Span Steel Truss Arch Bridge

The intelligent monitoring system for the entire construction process of large-span steel truss arch bridges mainly includes three parts: the intelligent monitoring system for the main bridge stress, the intelligent measurement system for the main bridge linear, and the automatic monitoring system for the anchor tower and anchor cables. Real time monitoring of tower misalignment, stress of key components and 3D coordinates during construction by using wireless stress-strain acquisition system, total station measurement robot, and GPS positioning technology. By analyzing potential adverse conditions through monitoring data and conducting error analysis, the construction stress and installation errors of the structure are controlled within the allowable range of the construction design, ensuring that the internal forces and linear of the structure meet the expected design values, and ensuring that bridge construction is in a controlled state.

Compared with traditional manual monitoring, intelligent monitoring systems are more convenient and do not require complex operations. Person with basic measurement knowledge can used. It should be noted that during the implementation of various automated monitoring, dedicated protection boxes should be set up for each transmission equipment to prevent equipment from being exposed to sunlight and long-term rainwater immersion. At the same time, electrical wiring should be set up to ensure the safety of construction electricity.

4.1 Automatic Monitoring System for Tower and Anchors

As shown in Figure 3, a schematic diagram of a GNSS（Global Navigation Satellite System）receiver is presented. GNSS monitoring stations are arranged at the top of the tower, fixed by welding and steel structure. By using each GNSS receiver in the GNSS deformation monitoring system, the raw data of GNSS is simultaneously output, and the relevant data is transmitted to the control center through a 4G module. Then, the control center obtains the raw real-time data stream of each monitoring point based on the IP address corresponding to each GNSS receiver, and performs unified calculation and analysis to achieve high-frequency dynamic three-dimensional deformation monitoring of tower top displacement.

Fig. 3. Schematic diagram of real-time monitoring points for anchor tower

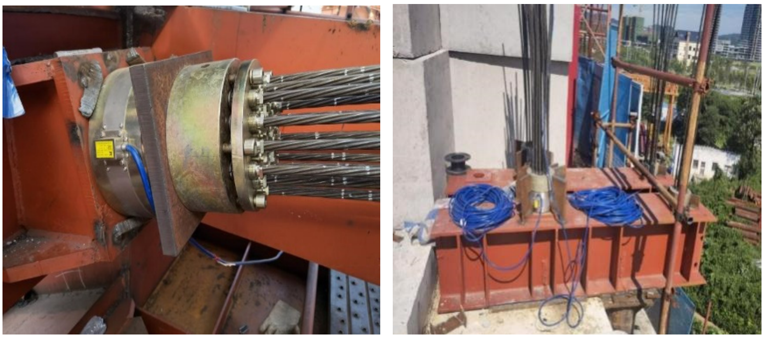

Fig. 4. Core type pressure sensor

As shown in Figure 4, the anchor cable strain acquisition sensor adopts a through type intelligent string anchor cable gauge, and transmits data to the backend server - the structural health monitoring "cloud plat-form" or the DTU mobile internet acquisition module through a 4G transmitter.

To ensure accurate numerical acquisition, the anchor cable gauge is equipped with six micro strain displacement sensors to verify the detection data. Built in intelligent chip facilitates digital detection and ensures distortion free long-distance signal transmission; Built in temperature sensor, automatically adjusts the temperature during the measurement process, eliminating the influence of temperature on the measured value.

4.2 Intelligent Monitoring System for Main Bridge Stress

The stress monitoring of the main bridge adopts a composite strain collection sensor, which is usually a surface vibration string strain gauge. The strain gauge mainly consists of a clamp, a steel string, a coil, and an installation head. The steel string is connected to the two end supports through the clamp, and is pre tensioned and fixed in the sensor, as shown in Figure 5. Based on the numerical calculation results of the cantilever assembly process of the large-span steel truss arch bridge, key nodes were selected for stress monitoring.

Fig. 5. Composite strain acquisition sensor

4.3 Intelligent Measurement System for Main Bridge Linear

The system mainly consists of an automated total station (measuring robot), an intelligent monitoring unit of the total station, an L-shaped prism, and an automated monitoring platform, as shown in Figure 6.

The total station intelligent monitoring unit controls the measurement robot to automatically complete periodic deformation monitoring. The data is uploaded to the automated monitoring platform through 4G network, and the platform calculates the deformation monitoring results in real time, displays the deformation trend, and automatically measures the three-dimensional data of the structure's line shape, elevation, and flat position during the steel truss arch cantilever assembly process. It is compared with the design state to evaluate the construction state.

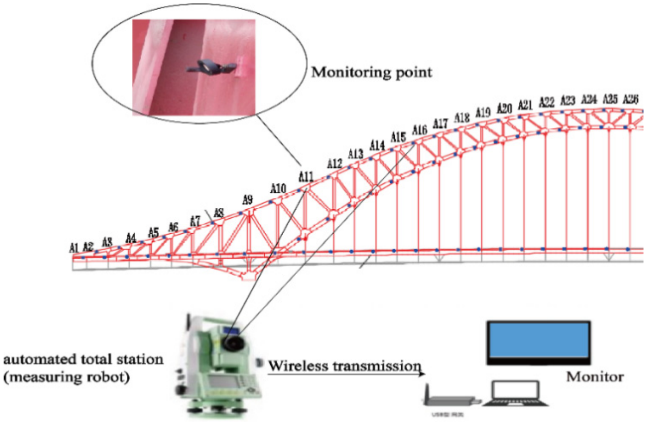

Fig. 6. Schematic diagram of measurement automation acquisition

4.4 Monitoring Results and Analysis

The intelligent construction decision-making system covers information on strain, stress, temperature, deformation, installation progress, and combined with construction monitoring parameters and design drawings to assist in decision-making on installation issues encountered during the construction of steel truss arch bridges.

The digital intelligent construction auxiliary decision-making system for large-span steel truss arch bridges has expansion interfaces that can adapt to the monitoring and analysis needs of other bridge projects besides arch bridges.

At the same time, corresponding warning thresholds were designed to provide real-time reminders through email and SMS, enabling construction decision-making, emergency warnings, and construction predictions throughout the entire process of bridge construction, as shown in Figure 7.

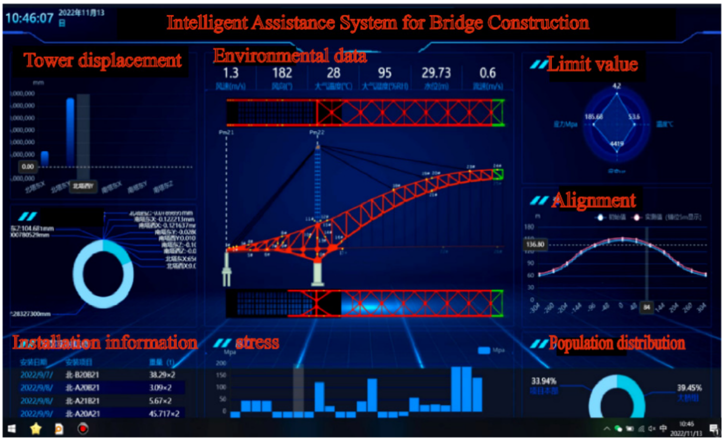

Fig. 7. Intelligent construction auxiliary decision-making system

5 Conclusions

Based on the actual construction situation of Qingshuitang Bridge, research was conducted on the digital intelligence technology of large-span steel truss arch bridge based on intelligent monitoring. An intelligent construction auxiliary decision-making system for large-span steel truss arch bridge was developed and successfully applied to project construction monitoring. The results showed that:

(1) The automatic monitoring system can timely record and analyze the displacement of the tower and the tension of the anchor cables, and can analyze whether there is a risk of overturning in the structure and whether the anchor cables are in a safe state, ensuring the safety of construction in a timely manner.

(2) The automatic monitoring system can record the temperature changes of the structure and has a good monitoring effect on the cable force of steel truss bridges. When analyzing the tension force, temperature correction is required, and the system can provide correction basis to ensure the stability of anti-overturning construction.

(3) The use of an automated monitoring system can significantly improve the construction monitoring efficiency of steel truss arch bridges. At the same time, the auxiliary decision-making system can timely reflect the structural stress, linear, and tower displacement under various construction conditions. The installation error value is automatically calculated in the background and reported to the project technical leader in a timely and accurate manner.

(4) The monitoring equipment used in this research institute can be quickly installed and disassembled, without affecting the maintenance and inspection of the steel truss arch bridge after completion.

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