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THE APPLICATION OF INTELLIGENT DIGITAL STRAIN SENSOR TECHNOLOGY IN STRUCTURAL CONSTRUCTION MONITORING

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ABSTRACT

Intelligent Strain Sensor JMZX-212 （ISSJ）is a kind of surface mounted strain gauge, which is used for measuring the strain of steel structure and concrete structure. It is suitable for long-term and automatic measurement. The application of ISSJ in climbing truss system for core tube structural construction is introduced. Then the data obtained were transferred into the stress and the internal force. By making a comparative analysis between the numerical simulation results and actual stress and strain, it is shown that the internal bearing force of primary truss is 70% of the design internal force in the process of construction, and 80% for the secondary truss. Steel truss platform performs well in bearing capacity and stiffness. Intelligent Strain Sensor is easy to install, and with the reliable results. It will be more and more widely used in structural construction monitoring.

Keywords: *Intelligent, Strain Sensor, Surface Mounted, Core Tube*

1. INTRODUCTION

There are many construction procedures and restricted factors when a super-high rise building is constructed, especially reinforced concrete structure. Traditional "building stocks step by step" method can only be applied to horizontal level construction and it is difficult to guarantee the quality in the premise of improving structural engineering construction speed. For tube in tube structure, wall-board separation construction method has effectively solved the requirement of the tall building engineering structural construction. Core tube construction has utilized the method of separating the vertical reinforced concrete and horizontal beam and combination floor structure. In this way, the vertical and horizontal construction can be separated in space and overlap in time. By setting a space distance between the vertical and horizontal structure construction, it is easy to apply the automatic control hydraulic jacking of climbing system to the construction platform. The steel truss platform can be taken as the purports for the climbing form system. It is quite necessary to monitor the strained condition of the truss [1] and the support column in the process of construction.

Experimental stress-strain analysis is widely used in the practical application of engineering. It has also obtained certain achievements in relevant aspects [2, 3]. Some researchers did deep research into the application of the Key engineering by using ROCTEST strain gauge [4]. And Others also did some research about the vibrating wire strain sensor of the measuring and testing techniques in the concrete [5, 6]. Modern detecting technique develops toward the direction of intelligence [7] and integration [8].

ISSJ is used for long-term observation. Before installation, it is need to install the coupons into the matched tong. Then gently remove the installation test bar after the tong is fixed, and put the surface strain

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gauge into the other side of the tong until in parallel with the edge of the tong. The measurement range of the surface strain sensor, or initial value, should be adjusted in the process of installation. At last, the clamping screw need to be tighten, and the reading meter of monitoring instrument can be connected.

ISSJ is designed with high-performance vibration exciter[9] and intelligent chip[10] set-in, which using the theory of vibrating string. The sensors can store parameters such as sensor model, electronic numbers, calibration coefficients, exit date and so on. Digital intelligent string strain sensors, by combining automatic integrated acquisition system, can achieve automatic measurement [11]. It can also realize the remote real-time monitoring if matches the radio transmitting equipment. A typical ISSJ is shown in the Figure 1.

2. ENGINEERING APPLICATION

2.1 General Introduction

The Beichen Urban Integrated Project, with a total construction area of 320497.56 square meters, and 4.2 meters standard story height, is located in Kaifu district in Changsha city. The highest elevation of structure is 248.62m, and the highest elevation of construction is 268.0m. It is frame with composite cube structure. Three floors of the building are under the ground, and 45 floors are on the ground. Every floor area is about 1756 square meters. The area of core cube is 450 square meters. The plan of the project is shown in Figure 2, and the standard floor plan of business building is shown in Figure 3.

2.2 Sensors Arrangement in the Truss

It needs a steel space truss to construct the building. As shown in design details, there are 2 primary trusses, 8 secondary trusses, 2 connective trusses and 5 main columns in this jacking creeping framework truss structure. The whole structure is not symmetrical. The three-dimensional diagram of the space structure is shown in Figure 4. Primary trusses 1 is supporting on the main column 1 and main column 3. The other, primary truss 2, is supporting on the main column 2 and main column 4. And all secondary trusses take the primary trusses as the supports。

Presently, primary truss 1 and secondary truss 4 are introduced as an example to illustrate the survey point. Three key sections of primary truss 1, as shown in Figure 5, lie in truss cantilever supporting place and mid-span. The sensors arrangement in primary truss 1 is shown in Figure 6.

Figure 1. Digital Intelligent String Strain Sensor

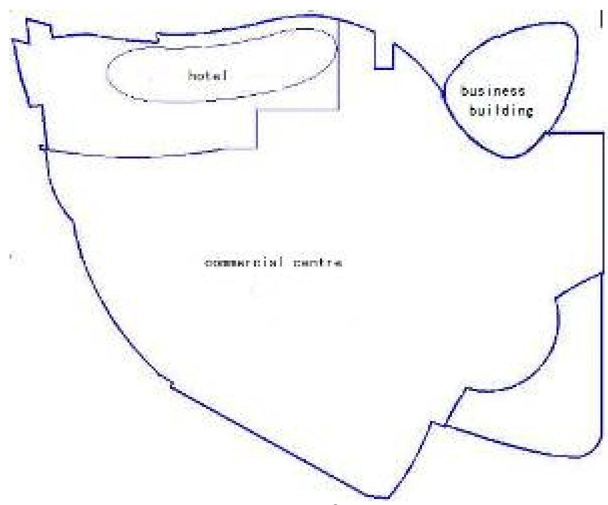

Figure 2. The Plan Of The Project

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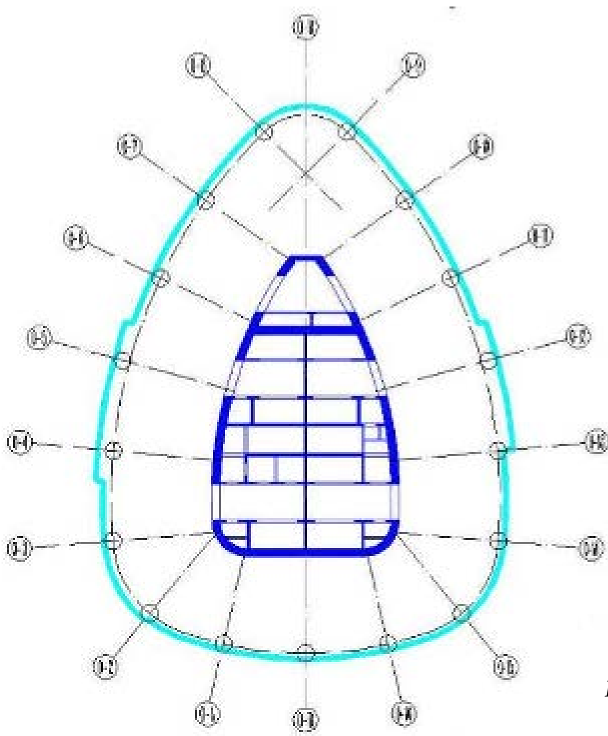


Figure 3. The Standard Floor Plan Of Business Building

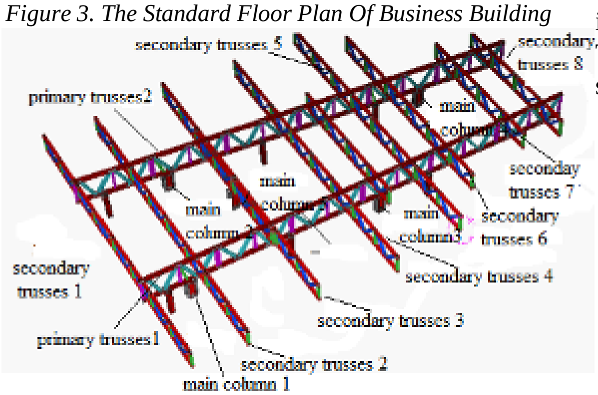


Figure 4. The Three-Dimensional Diagram

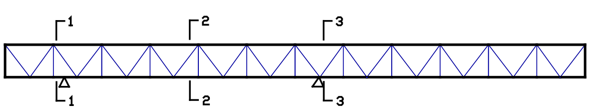
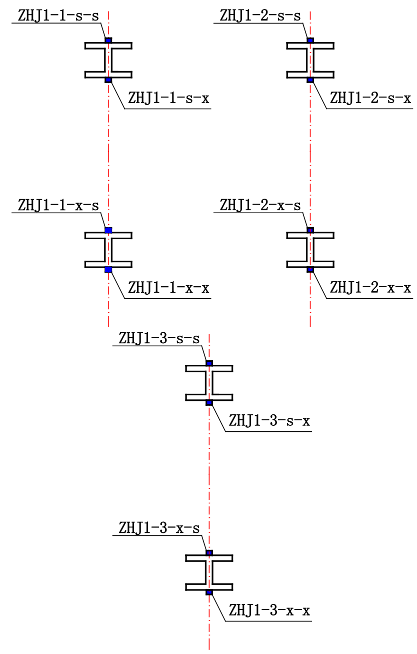


Figure 5. The Elevation Of Primary Truss1



a) section 1 b) section 2 c) section 3

Figure 6. The Sensors Arrangement Of Primary Truss 1

Two key sections of secondary truss 4, as shown in Figure 7, lie in truss cantilever supporting place. The sensors arrangement in secondary truss 4 is shown in Figure 8.

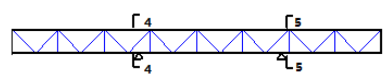
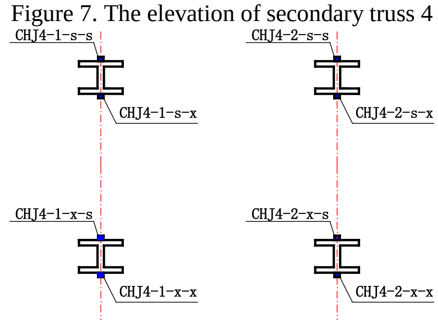


Figure 7. The elevation of secondary truss 4



a) section 4 b) section 5

Figure 8. The Sensor Arrangement Of Secondary Truss 4

Total 12 ISSJes were fixed up in 3 key sections (Every section contains 4 points, that are upper flange/ lower flange of the top chord, upper flange/ lower flange of the bottom chord) of primary truss 1. Similarly, on the left support, right support and mid-span of the primary truss 2, on the left support and right support of the secondary truss 1/2/5/6, the left support of secondary truss 7/8, 4 ISSJes were fixed up respectively. Slightly different, there were only 2 ISSJes fixed up on the left support and right

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support of the secondary truss 3. In addition, an ISDSG was set up on the 20 profiles of the 5 main columns. Hence, to sum up, there were 96 ISSJes fixed up in total.

3. DATA ANALYSIS

3.1 Result Analysis of Survey point 1

The key section of primary truss lies in truss cantilever supporting place and mid-span. There are four sensors on each section, and altogether 12 survey points in one primary truss. The survey point 1 lies in section 1 of primary truss 1, as shown in figure 6. From the data we measured, the maximum strain is 163.8, and the minimum strainis -248. The average strain is -117.6. The strain curve of the survey point 1 is shown in Figure 9. In which, the horizontal axis is corresponded to date, and the vertical axis is corresponded to strain.

The strain multiplies by the Modulus of Elasticity（if Q345 steel, it would be 206GPa) is the stress of the key section of primary truss. By which, it can be easily given that the maximum of the stress is 32.23MPa, the minimum is -51.088MPa and the average is -24.225MPa. The stress curve of the survey point 1 is shown in Figure 10. In which, the horizontal axis is corresponded to date, and the vertical axis is corresponded to stress.

In the same way, axial force on the bottom chord of the primary truss can be figured out. The maximum axial force is 552.3849KN, and the minimum axial force is -6.3778KN. The average axial force is 245.4174KN.The axial force curve of bottom chord is shown in Figure 11. In which, the horizontal axis is corresponded to date, and the vertical axis is corresponded to axial force.

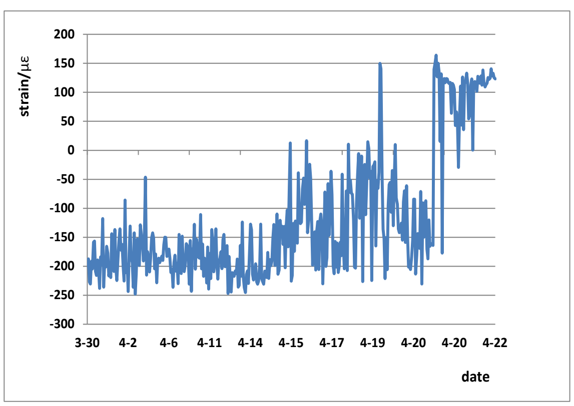

Figure 9. The Strain Curve Of The Survey Point 1

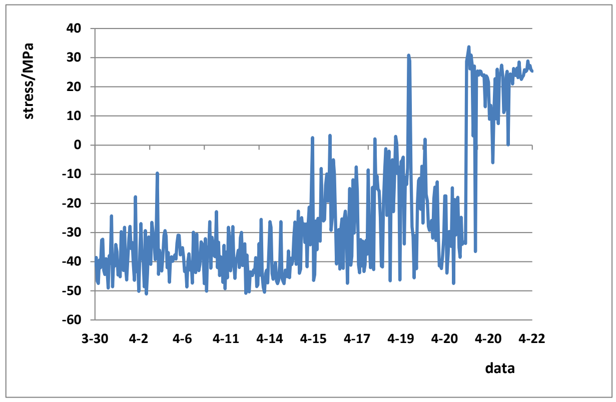

Figure 10. The Stress Curve Of The Survey Point 1

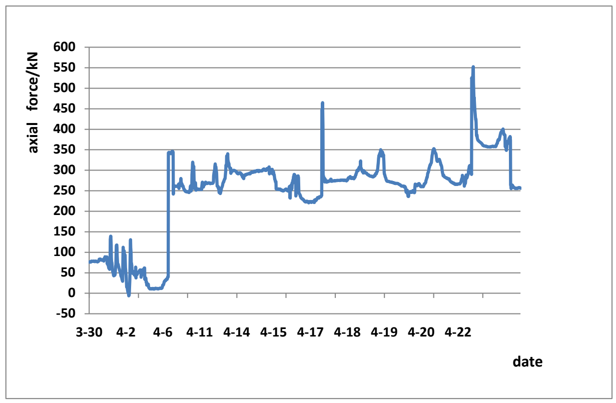

Figure 11. The Axial Force Curve Of Bottom Chord

3.2 Result Analysis of Survey point 2

The key section of secondary truss lies in truss cantilever supporting place. There are four sensors on each section and altogether 8 survey points in one secondary truss. The survey point 2 lies in section 4 of the secondary truss 4, as shown in figure 8. From the data we measured, the maximum strain was 17.4, and the minimum strain was -87.5 and the average strain was -27.1. The strain curve of the survey point 2 is shown in Figure 12. In which, the horizontal axis is corresponded to date, the vertical axis is corresponded to strain.

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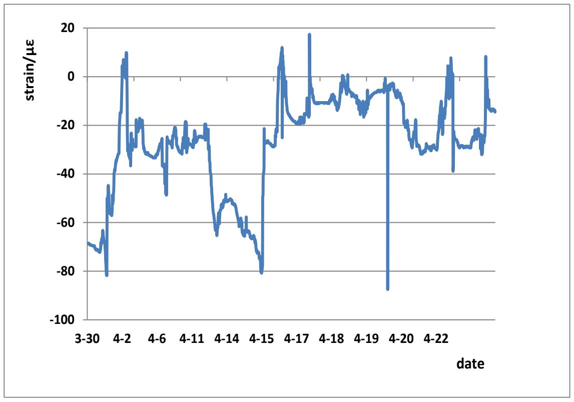

Figure 12. The Strain Curve Of The Survey Point 2

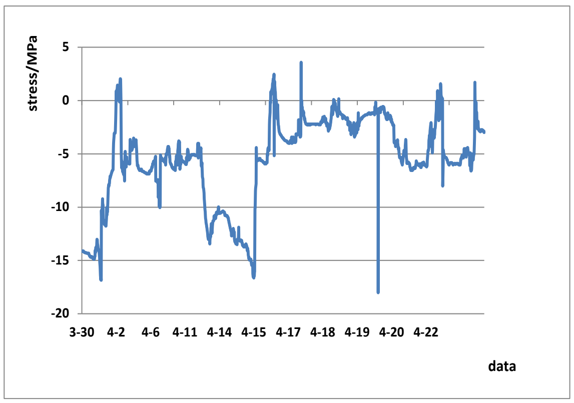

Figure 13. The Stress Curve Of The Survey Point 2

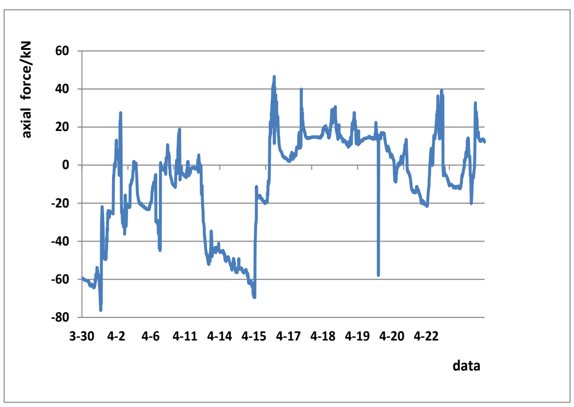

Figure 14. The Axial Force Deformation Of Top Chord

It can be easily to get the stress of the key section of secondary truss. The maximum of the stress is 3.5844MPa, the minimum stress is -18.025MPa and the average stress is -5.5772MPa. The stress curve of the survey point 2 is shown in Figure 13. In which, the horizontal axis is corresponded to date, and the vertical axis is corresponded to stress.

As survey point 1, axial force on the top chord of the secondary truss can be figured out. The maximum axial force is 53.4137KN, and the minimum axial force is -83.442KN. The average axial force is -8.8960KN. The axial force curve of bottom chord is shown in Figure 14. In which, the horizontal axis is corresponded to date, and the vertical axis is corresponded to axial force.

4. COMPARISON OF FINITE ELEMENT ANALYSIS

4.1 Establishment of the Model

SAP2000 is used for calculating and analyzing. According to the section size, load (dead load, live load, materials load, and wind load included) and constraint conditions of every components of the steel truss, the finite element model is set up as shown in Figure15 and Figure16.

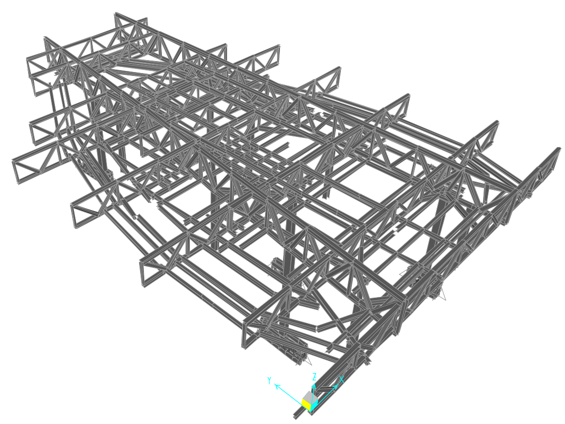

Figure 15. Model Of Finite Element

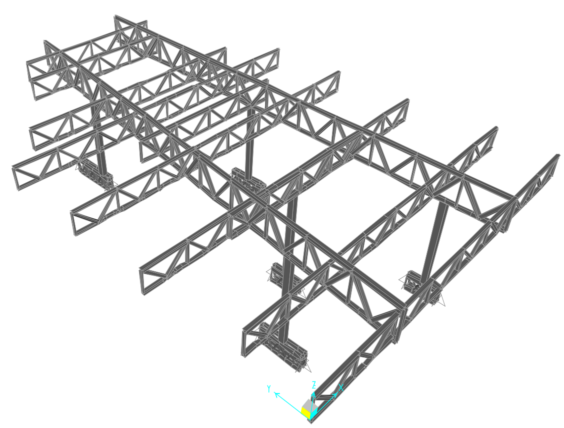

Figure 16. The Model Of The Main Structure

4.2 Finite Element Analysis Result

The maximum deflection of the steel truss is shown in Figure17.

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The ratio between truss stresses to steel strength is shown in Figure18 and Figure19.

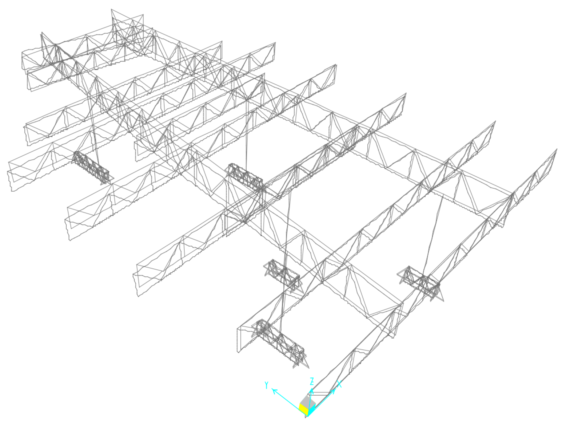

Figure 17. The Maximum Deflection Of The Steel Truss

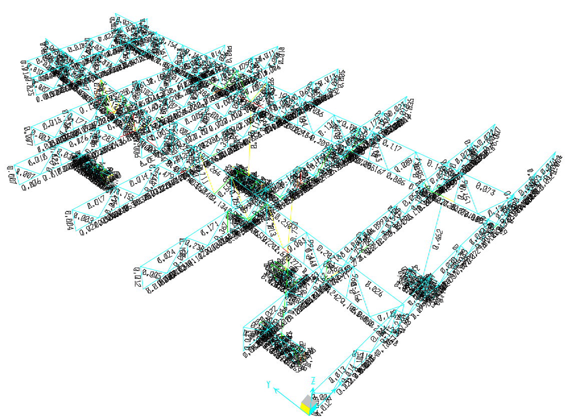

Figure 18. The Ratio Arrangement In Steel Truss

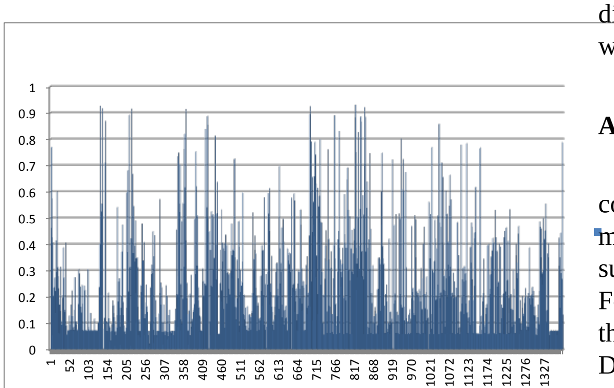

Figure 19. The Ratio Of Truss Stress To Steel Strength

4.3 Result Comparison Between Monitoring Data And FEA Simulation.

The maximum deflection of the primary truss is 51mm, which is approximately 1/417 of the span (21.3m), and meet the demand of the standard. The maximum deflection of the cantilever end is 120mm. The maximum designed stress ratio of the truss happen on the joints of the trusses. The maximum designed stress ratio of several chord member and web member were greater than 0.95 due to the concentrated forces at the joint of support. That can be reduced by designing the joints effectively. Most designed stress ratios of the members were less than 0.7, which meet the requirement of the standards.

5. CONCLUSION

According to the monitoring data, the strain, stress, axial force, moment of the primary truss and the secondary truss are analyzed in detail.

Compared to the calculated design stress and bearing capacity, the monitoring data of truss, strain, stress and internal force included, is in a relatively lower level.

Calculated design internal force is greater than force of structure in the actual construction process. The actual internal force accounted for about 80% of the design value, which indicates that truss system have certain safety redundancy. Both bearing capacity and stiffness of the overall truss structure performance well in the construction process. The load transformation in truss is relatively stable during various stages of construction.

It is shown that the application of the intelligent digital strain sensor has good prospects in structures which need a long-term monitoring.

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