Structural Health Monitoring for Construction Process of Gigantic Triangle Truss

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ABSTRACT

In order to study the stress distribution of the gigantic triangle truss of a stadium during lifting and unloading construction process, and meanwhile guarantee the safety of the construction, structural health monitoring system is applied on key members. Specific monitoring scheme has been made according to the mechanical characteristics of the gigantic triangle truss. In this case, a new Fiber Bragg Grating (FBG) strain sensor which is insensitive to temperature adopting a new way of encapsulation is presented for the steel truss. The monitoring results are analyzed.

1. INTRODUCTION

With the development science and technology, structures become more and more complicated. At the same time, there are more and more risks and problems during construction process. Nonetheless, aesthetically appealing from an architectural point of view, it is the trend that recent structures are much lighter, with relatively low first natural frequencies and significant motion amplitudes (Cigada 2010). If the structure becomes invalid or even collapses, it would cause serious sequences such as huge casualties and financial loss (Montalvao 2006). It is the priority to build a complete structural health monitoring system to ensure the construction process as smooth and safe as possible.

Strain as one of the basic mechanical parameters in a structural health monitoring system can make contribution to structural deformation, load identification and damage localization (Kefal 2016). Important as it is, various sensors have been developed to measure strain distribution such as conventional strain gauges and optic fiber sensors. In this paper, FBG strain sensor insensitive to temperature is introduced, which as the sensing subsystem is used to monitor the construction process of a gigantic triangle truss.

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2) Associate Professor
3) Professor

2. ENGINEERING BACKGROUND

A general view of the gigantic triangle truss structure is given in Fig. 1. It is originally designed as the main entrance of a stadium about 15m in height and 150m in span. Basically it’s consisted of two parts, one of which is truss system marked in red and the other is steel concrete reinforced frame column system marked in blue.

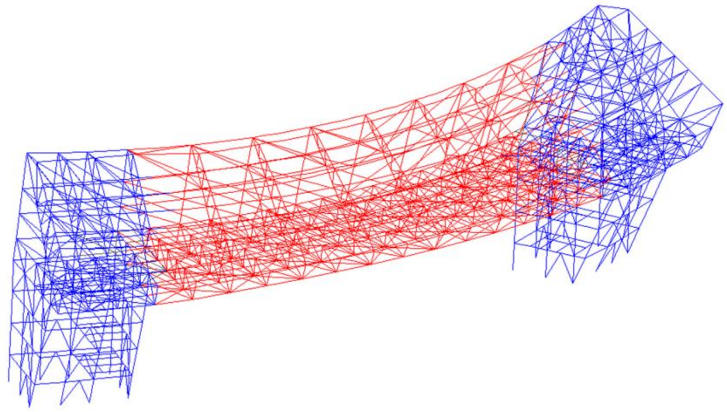

Fig. 1 A general view of the gigantic triangle truss structure

2.1 FBG Strain Sensor Insensitive to Temperature

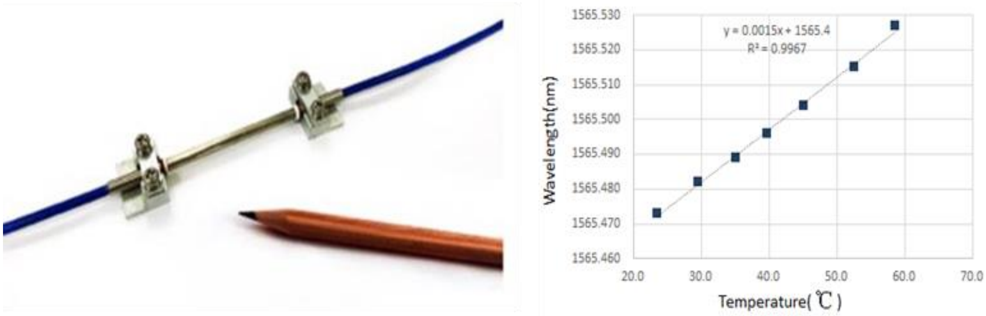

Fig. 2 FBG strain sensor insensitive to temperature

In this project, FBG strain sensor insensitive to temperature has been designed and developed, Fig. 2. A new way of encapsulation is adopted using negative thermal expansion material. Outside is a steel tube to protect the sensing part of the fiber. In the chart shown in Fig. 2 gives the relationship between the center wavelength of the sensor and temperature, from which it can be seen that the linearity is good and the temperature coefficient is 1.5 pm/℃.

2.2 Sensor Layout

The cross section of the truss system is in the shape of a triangle. A specific sensor layout scheme is illustrated in Fig. 3. In total it consists of three area including back side, front side and bottom side of the triangle truss. Considering the possibility of eccentricity, 4 FBG strain sensors are installed around the circular members of the monitoring points symmetrically. For the diagonal web members behaving as two-force rod in the whole system, only 2 FBG strain sensors are installed.

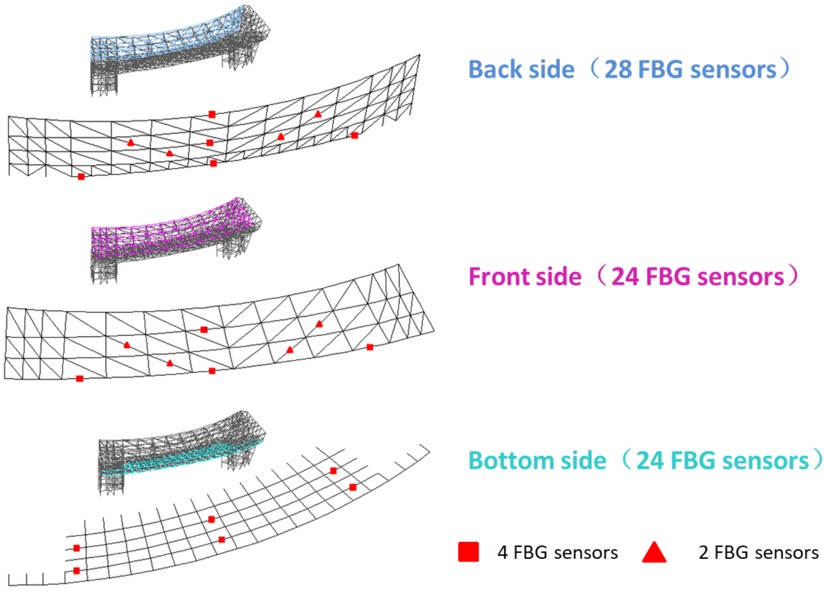

Fig. 3 FBG sensors layout

3. MONITORING RESULTS ANALYSIS

The truss system was at first assembled on the ground. Then on the top floor of both of the steel concrete reinforced frame column platform installed 10 steel brackets to lift the truss system up slowly with the aid of winding engine. After the elevating process, the truss system was welded to the cantilever beam of the adjacent structure with the steel strand still supporting the whole truss shown in Fig. 4. In the end, the internal forces in the strand will be released gradually which is the unloading process in this article.

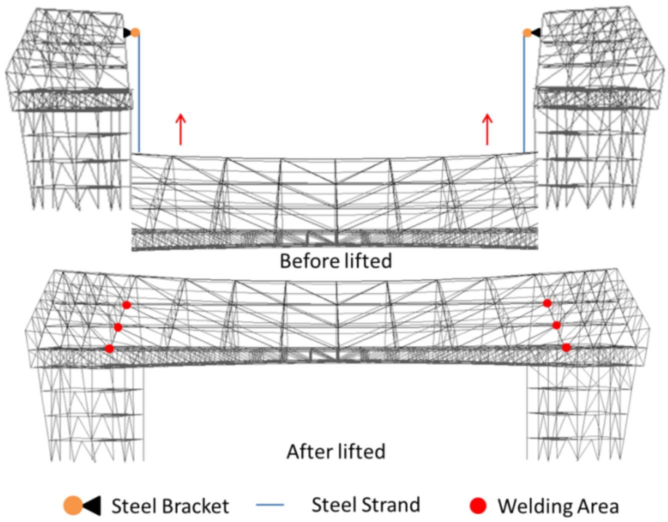

Fig. 4 The lifting process scheme

3.1 Monitoring Results of the Lifting Process

In order to test the lifting ability of the winding engine, the truss is pre-lifted during which the truss is lifted up about 1m high. The monitoring results of 4 FBG strain sensors of one monitoring point in bottom area of the truss is illustrated in Fig. 5 along with the cross section scheme of each sensor's specific position on the member. It can be seen that the first sensing area is in compression while the other three are in tension meaning that the member is subjected not only to axial force but also moment. Monitoring results are given in detail in Tab. 1. The maximum stress change is 38MPa proving that the truss is in safe condition.

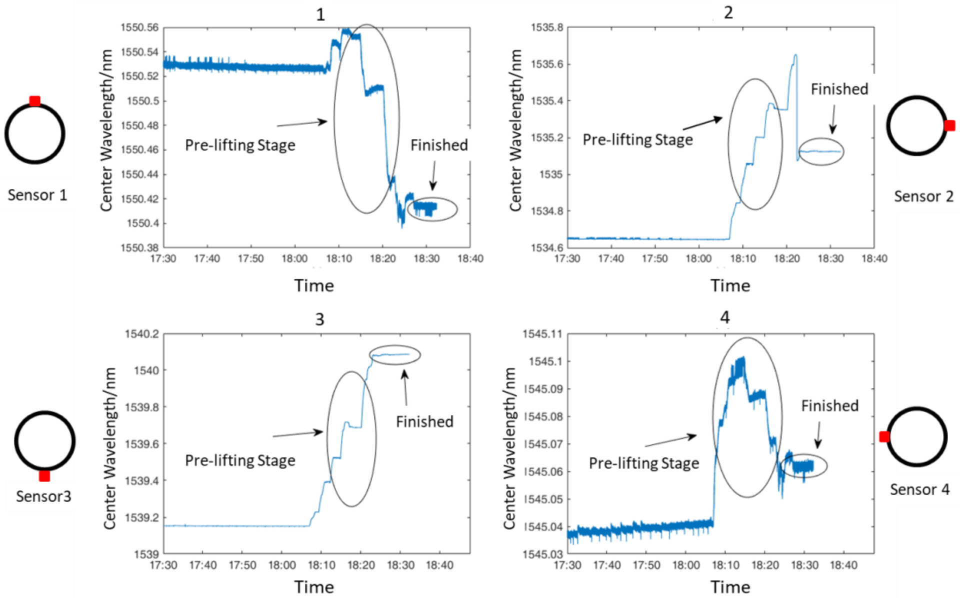

Fig. 5 Center wavelength time-history of FBG sensors in pre-lifting process

Tab. 1 Monitoring Results in pre-lifting process

Sensor No.	1	2	3	4
Wavelength Change/nm	-0.476	0.117	0.931	0.024
Stress Change/MPa	-19	5	38	1

During the lifting process, as a result of the asynchronism of each winding engine, there will be slight imbalance in elevating velocity causing the structural vibration which can explain the fluctuation in Fig. 6. The center wavelength of the FBG sensor before and after the lifting process stays at the same level indicating that there's no residual stress in the truss structure.

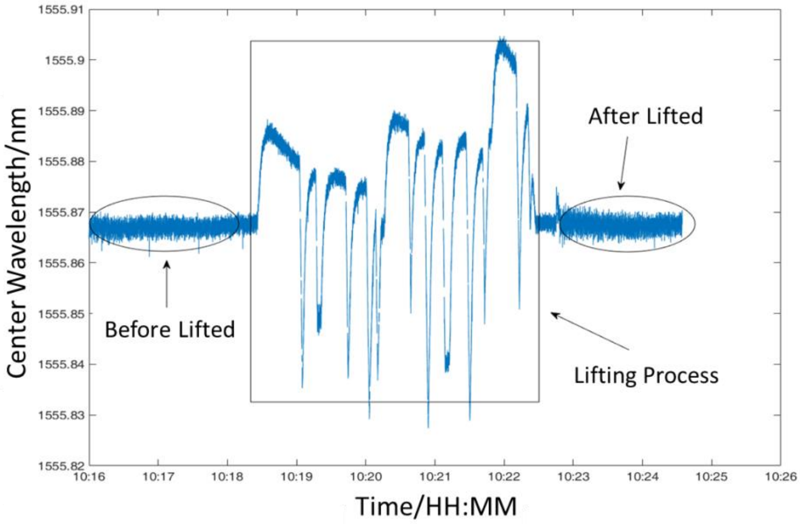

Fig. 6 Center wavelength time-history of FBG sensor in lifting process

3.2 Monitoring Results of the Unloading Process

The monitoring results of the unloading process of the same monitoring point mentioned above are shown in Fig. 7, from which it can be seen that the center wavelength changes are relatively little and all the sensors share the same various trend.

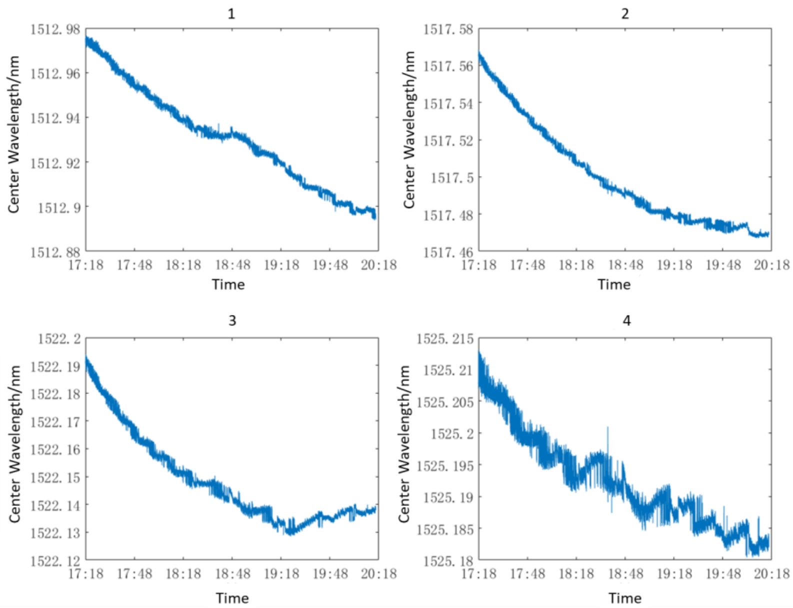

Fig. 7 Center wavelength time-history of FBG sensor in unloading process

4. CONCLUSION

In conclusion, the monitoring results have proven that the FBG strain sensors adopted in this project possess the ability of measuring strain of steel structures eliminating the temperature effect. Based on these results, the structural safety can be analyzed and evaluated.

REFERENCES

Cigada A, Moschioni G, Vanali M. (2010), “The measurement network of San Siro Meazza gymnasium in Milan: origin and implementation of a new data acquisition strategy for structural health monitoring”, *Experimental Techniques. J.*, **34**(1), 70-81

Montalvao D, Maia N.M.M, Ribeiro A.M.R. (2006), “A review of vibration-based structural health monitoring with special emphasis on composite materials”, *Shock and Vibration Digest. J.*, **38**(4), 295-326.

Kefal A, Oterkus E, Tessler A and Spangler J.L. (2016), “A quadrilateral inverse-shell element with drilling degrees of freedom for shape sensing and structural health monitoring”. *Engineering Science and Technology, an International Journal*. *J*., **19**(3), 1299-1313.