PERFORMANCE EVALUATION OF GERBER HINGES IN AN EXISTING STEEL TRUSS BRIDGE BY SHORT-TERM MONITORING

Nagaoka University of Technology Student Member ○Tran Duy Khanh
Nagaoka University of Technology Regular Member Takeshi Miyashita, Eiji Iwasaki, Masatsugu Nagai

1. INTRODUCTION

Target bridge in this study is the Chousei bridge, which is across the Shinano river in Nagaoka city (Fig. 1). This bridge was opened to the traffic in 1937. Its structural form is a steel Gerber (cantilever) through-truss bridge. The bridge consists of 13 spans with a total length of 850.8 m (span arrangement: 67.5 + 11@65.0 + 67.5m), and the concrete deck width is 7.0 m. Gerber hinges are at the end of upper chords in suspended spans. In 1995 to 1996, movable supports of these Gerber hinges were replaced to new ones, and bridge fall-prevention structures were also installed (Fig. 2). In June 2013, a proof loading test and a short-term monitoring were conducted to understand and evaluate the current condition towards the future maintenance because in-service period of the Chousei bridge is 77 years in this year.

2. OUTLINE OF MONITORING

The measurement items are strain, displacement and acceleration in each span. Temperature was also measured on a representative location near a vertical member in P6 to P7 span. The measurement locations of strain were the center of the upper chords in the downstream side. Moreover, in the suspended spans, the strain was measured on the two diagonal members connected towards the center of span from the Gerber hinges. The number of attached strain gauge on each selected cross section is 4 in order to separate the effect of axial force, in-plane and out-of-plane bending moments. To calculate resultant forces from the measured strains, the following equation is utilized.

$$\frac{1}{E}\begin{bmatrix} 1/A & 1/W_{z1} & 1/W_{y1} \\ 1/A & 1/W_{z2} & 1/W_{y2} \\ 1/A & 1/W_{z3} & 1/W_{y3} \\ 1/A & 1/W_{z4} & 1/W_{y4} \end{bmatrix} \begin{Bmatrix} N_x \\ M_z \\ M_y \end{Bmatrix} = \begin{Bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \end{Bmatrix} \tag{1}$$

where x, y and z are member coordinates shown in Fig.3, E is the Young's modulus of steel, A is area of cross section, W_{yi} and W_{zi} (i = 1, 2, 3, 4) are modulus of section, N_x is axial force, M_y and M_z are bending moments about y-axis and z-axis, respectively and ε_i is measured strain. Because the right hand side in Eq. (1) is known, it is possible to calculate the resultant forces N_x, M_y and M_z using the least square method. Total numbers of strain measurement points on the upper chord and the diagonal member are 52 (4 points / section × 1 point / span × 13 spans) and 48 (4 points / section × 2 points / span × 6 spans) respectively. The synchronized measurement was carried out by being the sampling frequency as 200 Hz. Monitoring period is 108 hours during 2:00 June 13th, 2013 to 14:00 June 17th. Furthermore, the traffic flow was recorded in video by a web camera installed on the P1 to P2 span. Due to the limit of paper length only the strains measured on the upper chords was reported.

3. PERFORMANCE OF GERBER HINGES

Minimum value of normal stress on the upper chord induced by axial force using Eq. (1) was -44.6 MPa in the 6th span during 4.5-day monitoring (Fig. 4(a)). Herein, measurement result (black line) is the summation of static component due to temperature change and dynamic component due to live load. Therefore, to separate both components, the static component is extracted by taking a moving average at each time (Fig. 4(a), blue line). As a result, the minimum value of the static component was -33.7 MPa in the 6th span. Since the 6th span is a suspended span, the static stress component due to temperature change should not be induced. However, by using the coefficient of linear thermal expansion for steel and the maximum temperature change during the monitoring period (Δt = 13 degrees, Fig. 5), the thermal induced stress calculated is -31.2 MPa. This indicates that the movable support of Gerber hinge in the 6th span is structurally deficient. The relationship between temperature and static component of normal stress is shown in Fig. 4(b). Furthermore, by subtracting the static component from the measurement result, the dynamic component due to live load is also obtained (Fig. 4(c)). Minimum value of the dynamic component is -19.7 MPa in the 4th span (Fig. 6). This also indicates that thermal induced stress exceeds live load caused stress by the fixing of the Gerber hinge. Therefore, if the Gerber hinges in the target bridge are repaired, priority should be given to the span that the fixing of movable support is confirmed.

Keywords: Steel truss bridge, Gerber hinge, Monitoring, Strain, Temperature stress
Contact address: Kamitomioka-cho, Nagaoka, Niigata, 940-2188, Japan, Tel: +81-258-47-9641

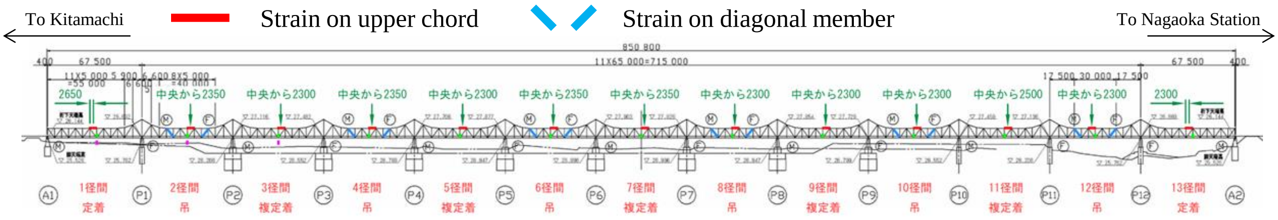


Fig.1 Measurement locations of strain

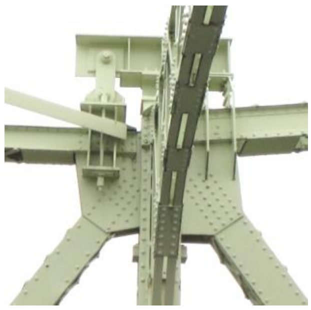


Fig.2 Gerber hinge

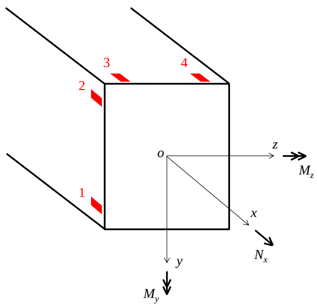


Fig.3 Member axes

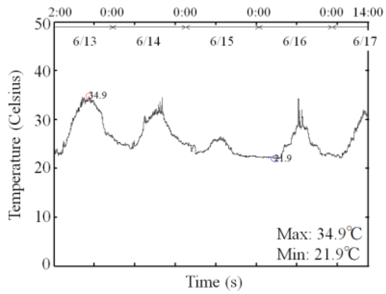
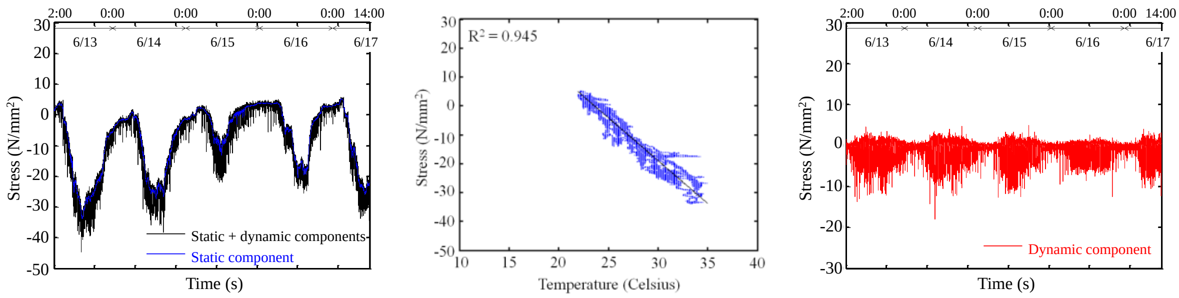
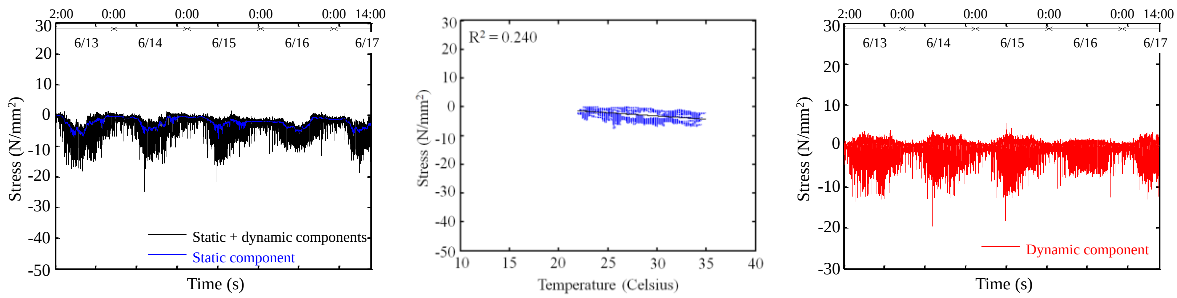


Fig.5 Temperature



(a) Static and dynamic components (b) Temperature and static component (c) Dynamic component

Fig. 4 Normal stress in the 6th span



(a) Static and dynamic components (b) Temperature and static component (c) Dynamic component

Fig. 6 Normal stress in the 4th span

4. CONCLUSIONS

In this study, the short-term monitoring was carried out for a steel Gerber through-truss bridge, which has been serving 77 years, to investigate and evaluate the current condition towards the future maintenance strategy. As a result, it found that a part of movable support of Gerber hinge was structurally deficient based on the relationship between temperature and measured stress on upper chords in the suspended spans.