ANALYSIS OF ENVIRONMENTAL EFFECTS ON A PC BOX-GIRDER BRIDGE USING LONG-TERM MONITORING DATA

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1. INTRODUCTION

It is well-known that the environmental factors, such as temperature, cannot be ignored in the analysis of Structural Health Monitoring (SHM) data through previous studies, e.g., [1] and [2]. This study is aimed to clarify the environmental effects on a target PC Box-Girder Bridge for the effective use of long-term SHM data in the structural condition assessment.

2. TARGET BRIDGE AND SHM SYSTEM

The research target in this study is a four-span continuous pre-stressed concrete box-girder bridge, which is located in the Niigata prefecture; one of the heaviest snowfall areas in Japan. In this bridge, a fiber-optic-base SHM system has been installed in one of the four spans since 2011. Here, the structural strain data has been acquired by eight fiber Bragg-grating (FBG) strain gauges; L1-1/2/3/4 and L3-1/2/3/4, as shown in **Fig.1**. **Fig.2** shows one of acquired strain data (Dec 2011-July 2014). It then shows strong seasonal and daily periodic trends that are considered to be due to the environmental effects. We firstly analyzed the correlation coefficients between the strain data and the environmental data including ambient air temperature, rainfall volume, and wind speed, time of sunshine, snowfall volume and snow accumulation volume, which were referenced from Japan Meteorological Agency.[3]

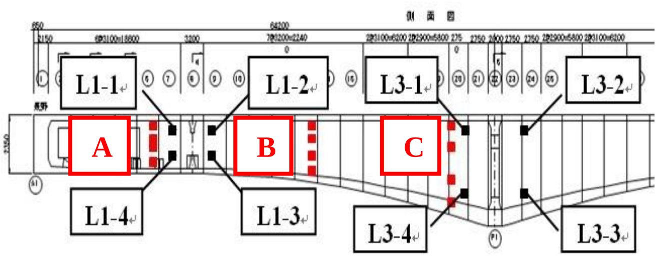

Fig.1 Locations of sensors

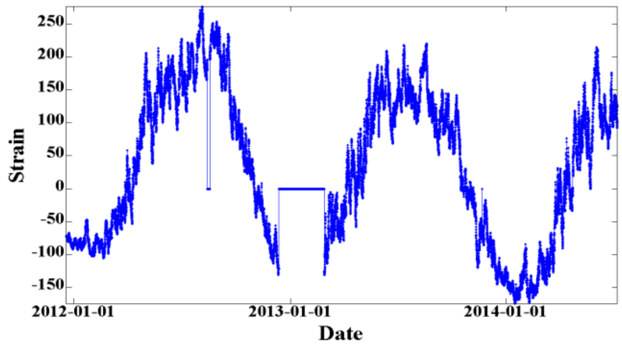

Fig.2 Strain data by time series in L1-1

The strain data of six sensors acquired from Dec. 19th, 2011 to July 8th, 2014 were used to be analyzed. **Fig.3** shows the calculated correlation coefficients with each of environmental factors. The results obviously showed the values between strain and air temperature, and the values between strain and snow accumulation were higher than the other factors; therefore, those two factors would be further discussed further.

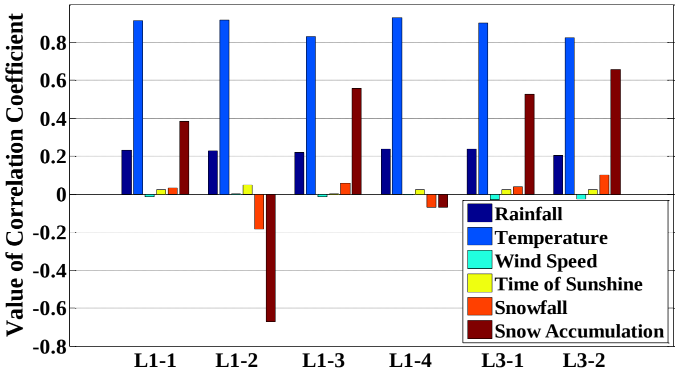

Fig.3. Values of correlation coefficients between strain and environmental factors

Table.1. Contributions of snow and thermal effects on each strain data

Sensors	Snow	Temp	Two Effects
L1-1	35.23%	59.59%	73.66%
L1-2	31.77%	63.75%	73.49%
L1-3	23.63%	50.15%	58.03%
L1-4	35.61%	59.21%	73.32%
L3-1	27.46%	56.72%	66.93%
L3-2	29.16%	57.80%	68.04%

3. REGRESSION ANALYSIS BETWEEN STRAIN DATA AND ENVIRONMENTAL FACTORS

The single and multiple linear regression analysis were adopted to find out contributions of air temperature and snow accumulation by the coefficient of determinations (R-square statistics). **Table.1** summarizes the calculated R^2-statistics of the snow accumulation and the air temperature on the strain data acquired just in winter season with accumulated snow. It can be seen that the contribution of temperature effect accounts for more than 50%, and the snow accumulation effect accounted for around 30% in all sensors. From results here, the temperature effect thus must be considered as the main effect on the structural strain behaviors, and moreover, the snow accumulation cannot be ignored in the data acquired in winter.

4. VERIFIACTION OF DETAIL TEMPERATURE EFFECT ON STRUCTURE

For the purpose of clarifying the detail temperature effect on the structural static behavior, the temperature distribution measurement was conducted for one year (Aug. 2013-July 2014) by attaching twenty-four thermal sensors on the bridge as shown in **Fig.4**. Three cross-sections (#A-C) were picked up as also indicated in **Fig.1**, and the sensors were attached on basically eight positions (#1-8) in each cross-section. The temperature distribution behaviors through one year could then be understood as below.

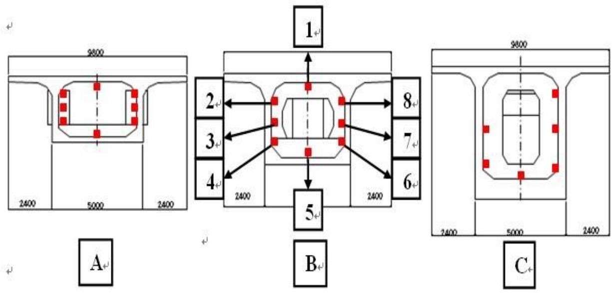

Fig.4. Locations of temperature sensors in cross-section A-C

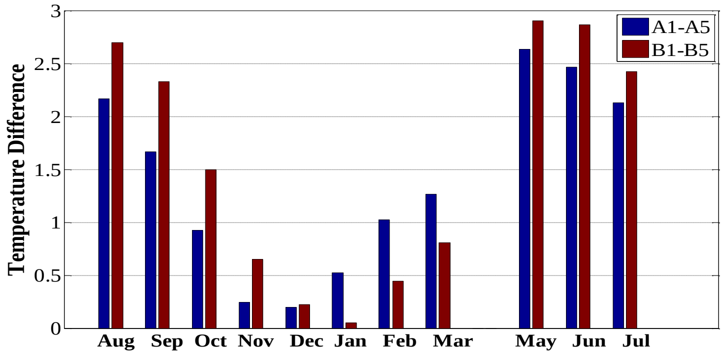

Fig.5. Temperature differences between top and soffit of box-girder inside girder in each month

(a)Temperature differences between top and bottom of the box-girder inside

The temperature difference between sensor location #1 and #5 (the value of #1 (top) - #5 (bottom)) in each cross-section were examined. **Fig.5** shows the averaged temperature differences in each month of 2013-2014. Firstly, the all temperature differences show positive values; this is due to the sunshine effect. The other point is; there is an apparent seasonal trend in the both cross-sections; such that the differences in summer and spring are larger than those in winter and autumn. Furthermore, section B, where is the mid-span, shows smaller temperature differences than those in section A only in the months with accumulated snow; i.e., December-March.

(b) Temperature Differences on Webs

The temperature difference between sensor location #8 and #2 (the value of #8 - #2), location #7 and #3 (the value of #7 - #3), location #6 and #4 (the value of #6 - #4) in each cross-sections were also examined. During long-term monitoring, the existence of temperature difference between left web and right web was proved. **Fig.6** shows the magnitudes of thermal effects on span longitudinal direction were different. (Section C > Section B > Section A). In short, along the span longitudinal direction, temperature differences increased. At the same time, in the vertical section direction, the bottom of temperature difference between two webs (A6-A4, B6-B4 & C6-C3) was larger than that in the upper parts (A8-A2 & B8-B2). In short, both in longitudinal direction of span and in box-girder section, temperature difference exist.

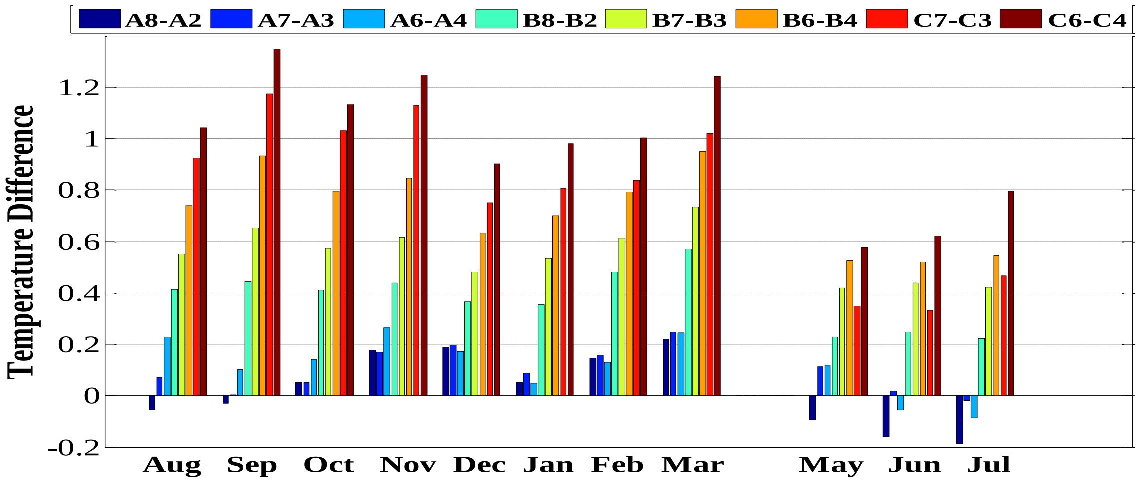

Fig.6. Mean value of temperature difference of two webs month by month (3 Sections)

5. CONCLUSION

This paper study on structural condition assessment considering different environmental effects based on Correlation Coefficient Analysis Method, Linear Regression Analysis. The temperature effect is considered as the main effect on the structural strain behaviors, and the snow accumulation cannot be ignored through analyzing. Furthermore, In PC box-girder bridge, both in longitudinal direction of span and in box-girder section, temperature differences exist.

REFERENCES

[1] Carin L, John E, Jason C. Measurements of Thermal Gradients and their Effects on Segmental Concrete Bridge. Journal of Bridge Engineering. May/June 2002. Page 166-174

[2] Nonthachart K, Pennung W. Structural health monitoring of continuous pre-stressed concrete bridge using ambient thermal response. Engineering Structures 40 (2012) Page 20-38.

[3] 気象庁 Japan Meteorological Agency. http://www.jma.go.jp/jma/index.html