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# DIAGNOSIS OF BRIDGE BEARINGS BASED ON FIELD MEASUREMENTS

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Bridge bearings are the structural members which are installed at the connection between superstructure and substructure in a bridge. They are expected to transfer load between superstructure and substructure, and to accommodate expansion and rotation of superstructure due to live load and temperature change. Bridges are designed based on whole structure models in which bearings show perfect performance. If bearings are deteriorated, the structure system of the whole bridge should be changed, and some damage may occur in superstructure and substructure. Therefore, it is of great importance to maintain bearings in good conditions. In this study, we try to establish quantitative evaluation method for required basic functions (load supporting, horizontal moving and rotating function) of bridge bearings as the structural member, through measuring displacement and stress in several highway bridges in the north area of Japan.

*Keywords*: Bearing function, Displacement, Strain, Fatigue life.

## 1 INTRODUCTION

Bridge bearings are the structural members which are installed at the connection between superstructure and substructure in a bridge. They are expected to transfer load between superstructure and substructure, and to accommodate expansion and rotation of superstructure due to live load and temperature change. Bridges are designed based on whole structure models in which bearings show perfect performance. If bearings are deteriorated, the structure system of the whole bridge should be changed, and some damage may occur in superstructure and substructure. Therefore, it is of great importance to maintain bearings in good conditions.

According to the reference (Ministry of Land, Infrastructure, Transport and Tourism 2014) for a bearing inspection, "Visual inspection" is prescribed as a standard method to inspect bearings, as well as "Measuring displacement" is recommended as an example which can be taken if necessary. However, practically, it is difficult to evaluate the deterioration degree of bearings by "Visual inspection" only. Moreover, any specific evaluation method for "Measuring displacement" has not been established.

In this study, we try to establish quantitative evaluation method for required basic functions (load supporting, horizontal moving and rotating function) of bridge bearings as the structural member, through measuring displacement and stress in several highway bridges in the north area of Japan.

## 2 METHOD

The evaluation method for the basic functions that are required to bearings and the measurement method are proposed as below.

### 2.1 Evaluation Method

The evaluation method was proposed for basic functions required for bearings as structural members for load supporting, horizontal moving and rotating respectively. The measurement items were vertical and horizontal displacements of bearings, and deterioration degree of bearings was evaluated with sequential transition of displacement measured. In addition, in order to verify effects of deterioration of the bearing functions on superstructure, stress of the girder lower flange was also measured.

### 2.2 Measurement Method

Figure 1 shows the locations of measuring displacements and stress. Vertical and horizontal displacements were measured by displacement transducers, and stress was measured by strain gauges pasted near the sole plate weld on the bottom surface of the lower flange. Measurements were conducted in two conditions, i.e. short-term measurement focusing on live load, and long-term measurement focusing on temperature change. Table 1 gives measurement conditions.

### 2.3 Objected Bridges

Table 2 gives detailed information of the objected bridges. They are three bridges with spherical bearings. The spherical bearing places between upper and lower shoes, allowing rotation by sliding along the spherical surface and horizontal movement by sliding on the flat surface. In all bearings, any corrosions and cracks were not detected and evaluated as sound by visual inspection.

## 3 RESULTS AND CONSIDERATIONS

For each object bridges, the bearing functions were evaluated based on the measurement results.

Table 2. Detailed information and measurement results of object bridges.

| Bridge | Bearing Type | Span length (m) | Completion year | ADTT (Vehicles /12h) |
|---|---|---|---|---|
| A | Spherical | 39.10 | 1989 | 981 |
| B | Spherical | 47.95 | 1988 | 1,434 |
| C | Spherical | 22.35 | 1996 | 2,509 |

### 3.1 Bridge-A

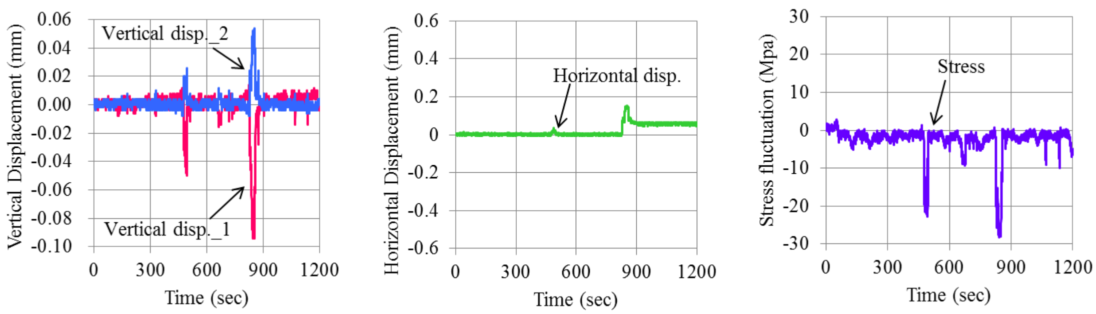
Figures 2 and 3 show the measurement results of Bridge A with Spherical bearing. Figure 2 and 3 indicate the short-term measurement results and the long-term measurement results respectively. Displacement 1 and Displacement 2 shows the center side of the span and the girder end. In short-term measurement, since vertical displacement was occurred in the vertical opposite direction in the front and back of the bearing and relatively large rotation, it was inferred that the bearing accommodated rotation due to live load. Horizontal displacement was occurred while rotating, but large stress fluctuation occurs, which indicates that the bearing has not move properly. In long-term measurement, although horizontal displacement occurred a little, stress fluctuation also occurs. It is assumed that the amount of displacement is sufficient for contraction due to temperature change comparatively, but is not sufficient for rotation due to live road.

### 3.2 Bridge-B

Figure 4 and 5 show the measurement results of Bridge B with Spherical bearing. In short-term measurement results, rotation by live load has occurred, but horizontal displacement has not occurred at all. At this time, stress fluctuation has also occurred, and it could be determined ems that the bearing has not rotated smoothly. Also in long-term results, horizontal displacement by temperature change has hardly occurred, and stress fluctuation has also occurred. When stress fluctuation was confirmed, it revealed that neither rotation function nor horizontal movement function is working.

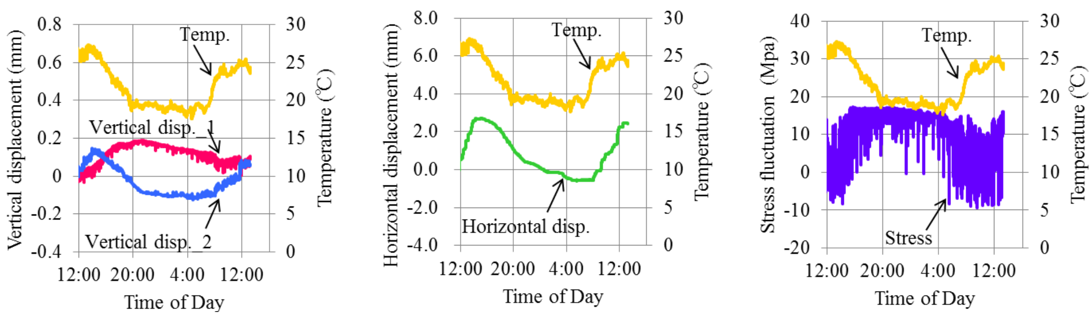
### 3.3 Bridge-C

Figure 6 and 7 show the measurement results of Bridge C with Spherical bearing. In short-term measurement results, bearing has rotated and moved horizontally but not gone back to original position neither, and small stress fluctuation was recognized. Moreover, in the long-term results, horizontal displacement due to temperature change occurred, but stress fluctuations also occurred moderately. Although rotation and horizontal movement are not perfect, the stress fluctuation has been smaller than that of bridge A and B.



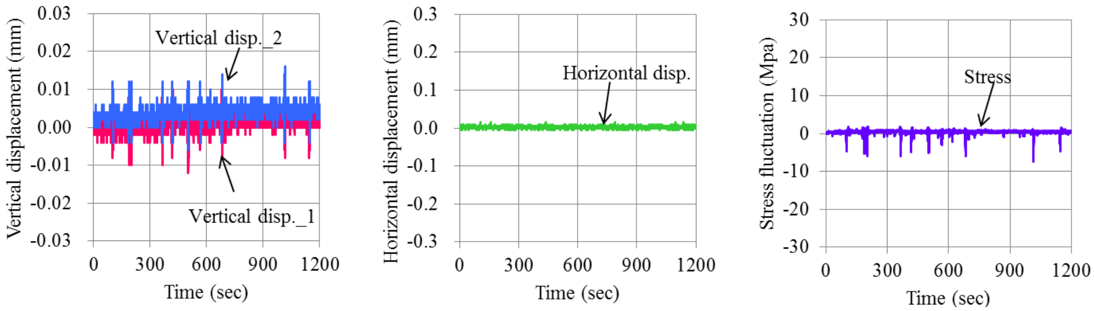

(a) Vertical displacement (b) Horizontal displacement (c) Stress fluctuation

Figure 2. Short-term measurement results of Bridge A.



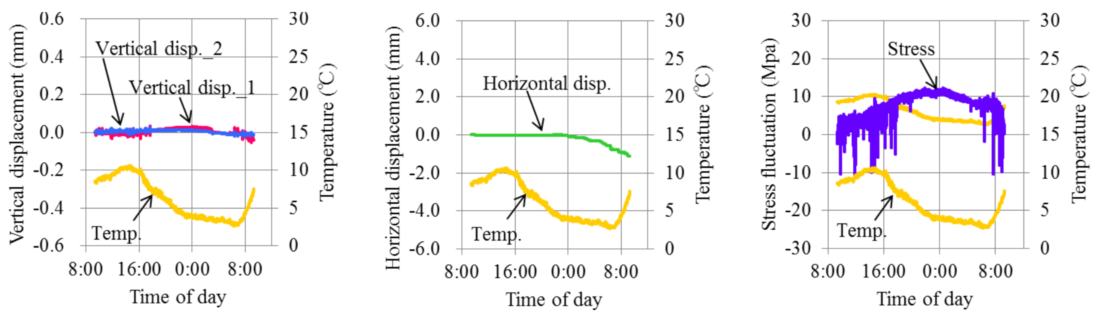

(a) Vertical displacement (b) Horizontal displacement (c) Stress fluctuation

Figure 3. Long-term measurement results of Bridge A.



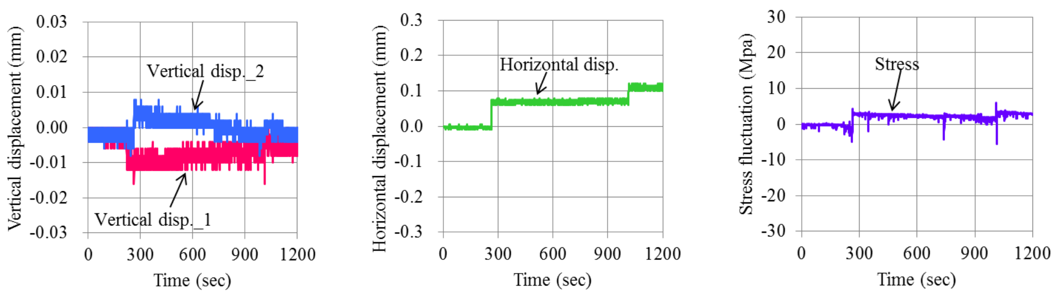

(a) Vertical displacement (b) Horizontal displacement (c) Stress fluctuation

Figure 4. Short-term measurement results of Bridge B.



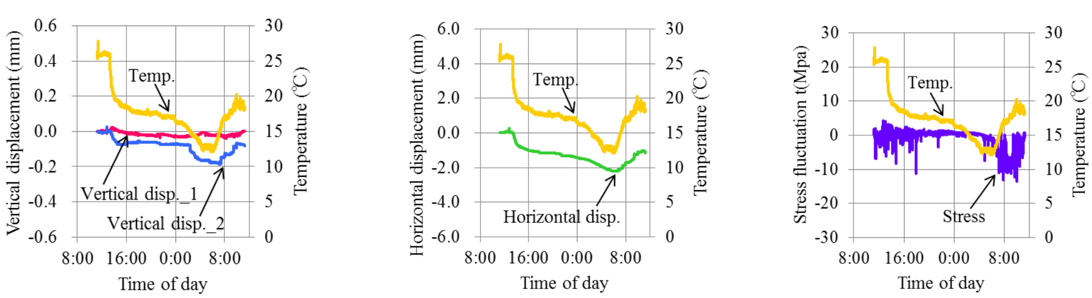

(a) Vertical displacement (b) Horizontal displacement (c) Stress fluctuation

Figure 5. Long-term measurement results of Bridge B.




(a) Vertical displacement (b) Horizontal displacement (c) Stress fluctuation

Figure 6. Short-term measurement results of Bridge C.




(a) Vertical displacement (b) Horizontal displacement (c) Stress fluctuation

Figure 7. Long-term measurement results of Bridge C.

## 4 EVALUATING DETERIORATION DEGREE OF BEARINGS

We tried to evaluate the deterioration degree of the bearings by the stress and the fatigue life of lower flanges in the main girder.

### 4.1 Calculating Fatigue Life

The fatigue curve used for the fatigue life calculation was the one, which was the lowest category H' in the reference (Japan Road Association 2002), and the endurance limit was used as 7 MPa. Moreover, for the calculation of frequency distribution of the stress range, the rain-flow method, which is the most common, was used. In addition, the correction coefficient by the structure details was not taken into account.

### 4.2 Correlation between the Functional Evaluation and the Fatigue Life

Focusing on short-term measurement results, fatigue life with large rotation angle was shorter than with smaller rotation angle. It indicates that bearing with large rotation angle is not more soundness. Also, in the long-term results, the fatigue life of the Bridge-A with large horizontal displacement is the shortest, and it could not be determined that the bearing with large horizontal displacement is sound. The rotation and horizontal movement required for the support part are different for each bridge and it is difficult to quantify it. Therefore, it is almost impossible to estimate to what extent the measured rotation and horizontal movement among rotation and horizontal movement required for the bearing. The other hand, in both measurement results of short-term and long-term, the maximum stress range and fatigue life are completely inversely proportional. It is inferred that fatigue life could be estimated by measuring stress fluctuation.

Table 3. Measurement results and fatigue life.

| Bridge | Rotation angle (rad) | | | Temp. change (℃) | Horizontal disp. (mm) | | |
|---|---|---|---|---|---|---|---|
| | Short-term | Long-term | | Long-term | Short-term | Long-term | |
| | ① | ② | ①/② | - | ① | ② | ①/② |
| A | $3.050 \times 10^{-4}$ | $7.911 \times 10^{-4}$ | 0.385 | 9.7 | 0.160 | 3.33 | 0.048 |
| B | $0.611 \times 10^{-4}$ | $1.443 \times 10^{-4}$ | 0.423 | 8.0 | 0.020 | 1.15 | 0.017 |
| C | $0.506 \times 10^{-4}$ | $4.744 \times 10^{-4}$ | 0.106 | 15.8 | 0.130 | 2.52 | 0.052 |

| Bridge | Maximum stress range (Mpa) | | | Fatigue life (years) | |
|---|---|---|---|---|---|
| | Short-term | Long-term | | Short-term | Long-term |
| | ① | ② | ①/② | - | - |
| A | 31.2 | 26.8 | 1.164 | 29 | 131 |
| B | 10.3 | 23.0 | 0.448 | 182 | 666 |
| C | 11.4 | 17.8 | 0.640 | 353 | 1,501 |

## 5 CONCLUSIONS AND FUTURE LINE OF RESEARCH

As a result of the measurements of vertical and horizontal displacements and the stress of the main girder lower flanges, the following conclusions were obtained.

(1) As measuring vertical and horizontal displacements for 20 minutes, it becomes possible to evaluate rotation and horizontal movement due to live load.

(2) As measuring vertical and horizontal displacement for one day, it becomes possible to evaluate rotation and horizontal movement due to temperature changes.

(3) It is difficult that the soundness of the bearing be estimated by the rotation angle and the horizontal displacement of bearing.

(4) It is inferred that fatigue life could be estimated by measuring stress fluctuation.

Thus, we consider that effectiveness of the bearing function evaluation method proposed in this study is validated. Hereafter, we would like to establish more precise and practical evaluation methods by increasing a number of measurement cases.

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