Integrated Solutions for Infrastructure Development
Edited by Lau, H. H., Tang, F. E., Ng, C. K., and Singh, A.

ISBN: 978-0-9960437-3-1

DIAGNOSIS OF BRIDGE BEARINGS BASED ON FIELD MEASUREMENTS

NAHO SHIBASAKI[1], MARIKO IKEDA[2] and MASAHIRO SAKANO[3]

[1] *Kawakin Core-Tech CO., Ltd., Osaka, Japan*
[2] *Kajima Corporation, Tokyo, Japan*
[3] *Kansai University, Osaka, Japan*

Bridge bearings are the structural members which are installed at the connection between superstructure and substructure of a bridge, thus it is crucial to maintain bearing functions as structural members. If bearing functions are declined, it is possible for the structure of the whole bridge to be changed and have an effect on functions of superstructure and substructure. Thus, maintaining functions of bearings is not negligible. Generally, "Visual inspection" is indicated as a standard method. However, it is difficult to evaluate the deterioration degree of bearing functions with "Visual inspection" only. Therefore, we have studied to establish a qualitative evaluation method regarding basic functions required for bridge bearings as structural members based on measuring displacement and strain. In this study, measuring displacement and strain in the bridge in service was carried out, and evaluating the deterioration degree of bearings with the evaluation method proposed was attempted.

Keywords: Bearing, Highway bridge, Displacement, Strain, Fatigue life.

1 INTRODUCTION

Bridge bearings are the structural members which are installed at the connection between superstructure and substructure of a bridge. Their functions are expected to transfer load which acts on superstructure to substructure and accommodate expansion and rotation of superstructure, due to live load and temperature variations, in order to absorb relative displacement of superstructure and substructure. Bridge design is based on whole analysis models which the bearing functions are reflected. If bearing functions are deteriorated, the structure system of the whole bridge can be possibly changed, and it may affect on functions of superstructure and substructure. Thus, it is crucial to maintain bearing functions as structural members. According to the reference (Ministry of Land, Infrastructure, Transport and Tourism 2014) for a bearing inspection, "Visual inspection" is shown as a standard method to inspect bearings, as well as "Measuring displacement" is shown as an example which can be taken if necessary. However, in reality, it is difficult to evaluate the deterioration degree of bearing functions with "Visual inspection" only. Moreover, any specific evaluation method for "Measuring displacement" has not been established. In this case, with consideration of these points above, we have studied to establish qualitative evaluation methods regarding required basic functions (load supporting, horizontal moving and rotating function) for bridge bearings as structural members based on measuring displacement and strain.

In this study, measuring displacement and strain in the bridge in service was carried out to attempt evaluating the deterioration degree of bearings with the evaluation method we proposed.

2 METHOD

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

2.1 Evaluation Method

The evaluation method was set for basic functions required for bearings as structural members for load supporting, horizontal moving and rotating function respectively. The measurement items were vertical and horizontal displacement of bearings, and deterioration degree of bearings was evaluated with sequential transition of displacement measured. Table 1 shows details of the evaluation method and measurement items. In addition, in order to verify effects of deterioration of the bearing functions on superstructure, strain of the girder lower flange was also measured.

Table 1. Evaluation method and measurement item for bridge function.

Basic functions required for bearings	Evaluation method	Measurement items
Load supporting function	Checking if vertical supporting function is deteriorated that the whole bearing is moved up and down	Vertical displacement in the front and back in the longitudinal direction
Rotating function	Checking if the bearing can accommodate rotation due to girder deformation due to live load	Vertical displacement in the front and back in the longitudinal direction
Horizontal moving function	Checking if the bearing can accommodate horizontal movement due to girder deformation due to live load and temperature changes	Horizontal relative displacement of superstructure and substructure in the longitudinal direction
Effect on girder	Checking if large stress fluctuation occur at lower flange due to bearing function deterioration	Stress fluctuation at lower flange bottom of the girder located 20mm from weld toes of the sole plate

2.2 Measurement Method

Figure 1 shows the measurement position of displacement and strain. Displacement transducers were used to measure vertical and horizontal displacement, and stress was measured with a strain gauge, which is installed just before measuring, at the bottom of the lower flange. Measurements were conducted in two conditions, short-term and long-term. Short-term measurement focuses on live load, whereas long-term measurement focuses on temperature variations. Table 2 shows the detailed measurement conditions respectively.

Table 2. Evaluation method and measurement items for bridge functions.

Measurement type	Action	Period	Frequency
Short-term	Live load	20 minutes	200 Hz
Long-term	Temperature Change	1 day	0.5 Hz

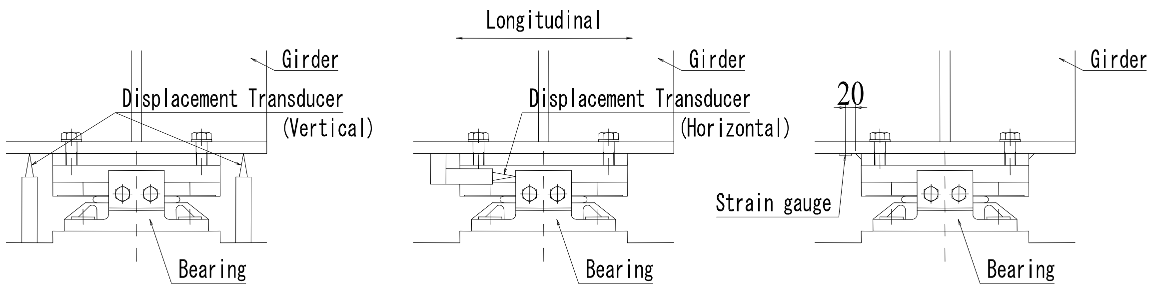

Figure 1. Measurement positions.

2.3 Measurement Object

Table 3 shows the measurement objects, the four bridges have bearings of different types. All of the bearings whose corrosions and cracks were not recognized were evaluated as sound in a visual inspection.

Table 3. Evaluation method and measurement items for bridge functions.

Bridge	Bearing Type	Span length (m)	Horizontal alignment(m)	Completion year	ADT (Vehicles/day)
A	Spherical bearing	30.0	R = 35	1986	21,179
B	Rubber bearing	202.65	R = ∞	2006	85,684

3 RESULTS AND CONSIDERATIONS

For respective object bridges, the bearing functions were evaluated by the measurement results verified.

3.1 Spherical Bearing

Figure 2 shows the measurement results of Bridge A with Spherical bearing. Graphs of (a) to (c) are extracted for 15 seconds from the short-term measurement results, while the graphs of (d) to (f) are for the long-term measurement results. Since vertical displacement was occurred in the vertical opposite direction in the front and back of the bearing, it was inferred that the bearing accommodated rotation, due to live load and temperature variations in short-term and long-term measurement. Meanwhile horizontal displacement was occurred in neither short-term nor long-term measurement, which indicates that the bearing did not move horizontally. It was because curvature radius of the horizontal alignment is small, thus, the moving direction of superstructure is inconsistent with the horizontal movement of the bearing because superstructure is just moved in the longitudinal direction. It is considered that the fixing structure in the transverse direction restrains deformation of superstructure. Moreover, in both short-term and long-term measurement, horizontal displacement was not occurred when vertical displacement was occurred, and stress fluctuation was occurred in the girder lower flange, thus it can be inferred that the horizontal moving function has some issues.

3.2 Rubber Bearing

Figure 3 shows the measurement results of Bridge B with Rubber bearing. In the short-measurement, from the fact that vertical displacement was occurred downward in the front and back of bearing, it can be inferred that bearing was compressed, due to live load. Due to that magnitude of vertical displacement in the front and back of bearing was different; it can be also presumed that the bearing accommodated rotation by live load. In the short-measurement, the fact, which vertical displacement in the front and back of the bearing was occurred upward with the temperature rise and downward with temperature fall, indicates that the bearing was expanded and contracted with the temperature variations. However, stress fluctuation was recognized when rotation and horizontal movement was occurred in both of the short-term and long-term measurements, thus it is confirmed that the bearing does not completely accommodate deformation of superstructure.

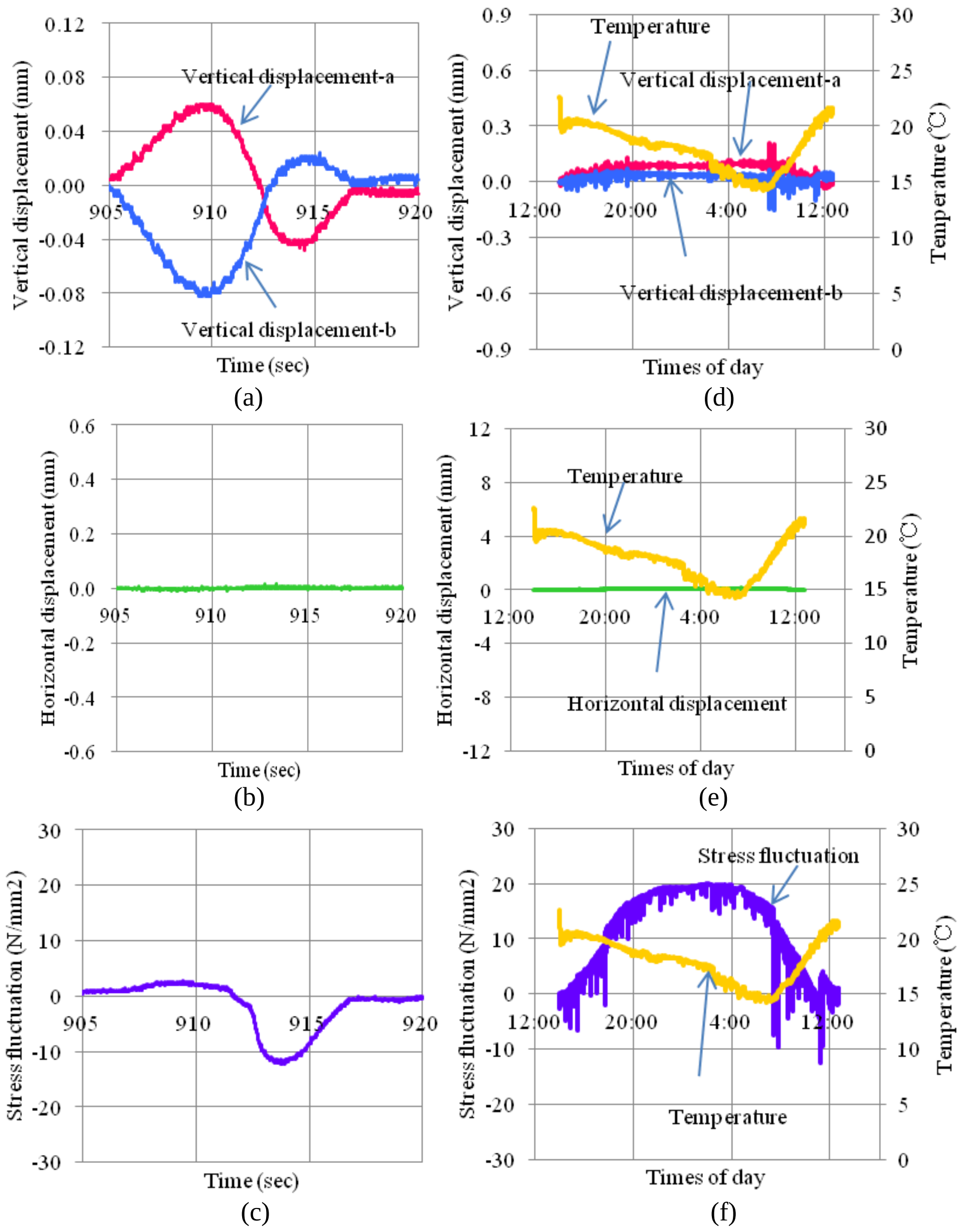

Figure 2. Results of Bridge A with Spherical bearing.

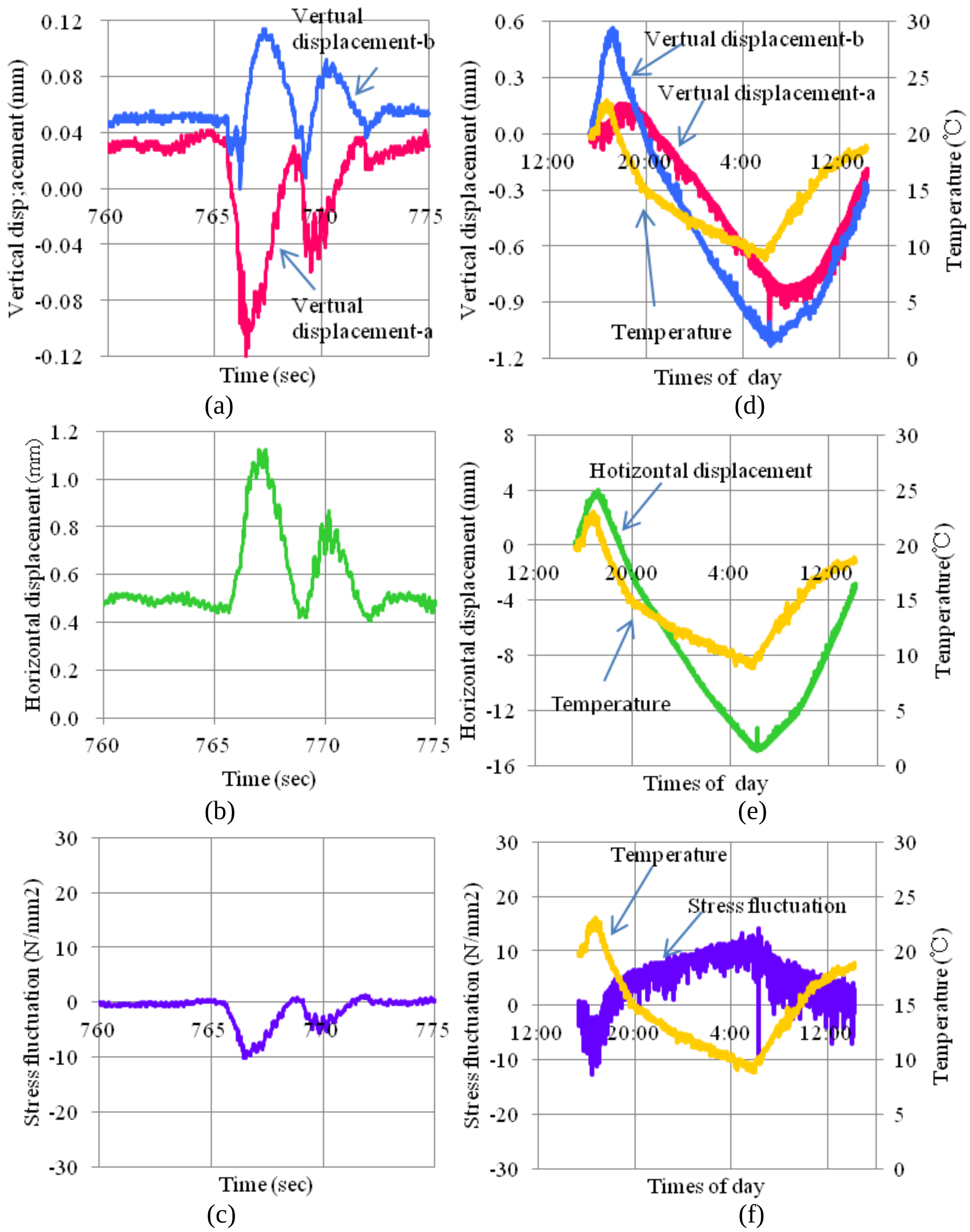

Figure 3. Results of Bridge B with Rubber bearing.

4 RESULTS AND CONSIDERATIONS

We attempted to verify the correlation between the functional evaluation and the fatigue life which is calculated with measurement results of the stress fluctuation.

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

Regarding the fatigue life of Rubber bearing which rotates and moves horizontally, is relatively long, meanwhile, the fatigue life of Spherical bearing which rotates and does not move horizontally at all, is relatively short. The fatigue life of Rubber bearing which has rotating and moving functions, is the shorter than Spherical bearing. It can be considered that what constant stiffness of Rubber bearing occurs resistance force against rotation and movement of superstructure is one of the causes. Moreover, it can be inferred as one of the factors that the traffic volume of large vehicles in the object bridges is heavy. In case of Rubber bearing, even if bearings have rotation and moving functions in certain levels, the fatigue life can become relatively short dependent on traffic volume of large vehicles.

Table 4. Fatigue life.

Bridge	**Bearing Type**	**ADTT (Vehicles/day)**	**Fatigue life (years)**	
			Short-term	**Long-term**
A	Spherical bearing	4,294	233	1691
B	Rubber bearing	7,800	71	864

5 CONCLUSIONS

As a result of the measurements of vertical and horizontal displacements and the strain of the girder lower flange with functional evaluation methods, the following knowledge was gained.

(1) As measuring vertical and horizontal displacement for one day, it becomes possible to evaluate rotation and horizontal moving functions to accommodate deformation of superstructure due to temperature variations.

(2) As measuring vertical and horizontal displacements for 20 minutes, it becomes possible to evaluate rotation and horizontal moving functions to accommodate deformation of superstructure due to live load.

(3) Even if rotation and movement is occurred in a bridge which may have heavy traffic with large vehicles and whose fatigue damages are concerned, necessity of measurements of stress fluctuation in the girder lower flange as well as vertical and horizontal displacements is still considered.

From above, 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 with increasing a number of measurement times.

This research was financially supported by the Kansai University Grant-in-Aid for progress of research in graduate course, 2015.

References

Japan Road Association, Fatigue Design Recommendations for Steel Highway Bridges, 2002.
Ministry of Land, Infrastructure, Transport and Tourism, Bridge Inspection Manual, 2014.