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Functional evaluation of bridge bearings based on the field measurement

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1 INTRODUCTION

Bridge bearings are the structural members to install in the connection between superstructure and substructure of bridges, in order to transfer load, which acts on superstructure, to substructure reliably and follow expansion and rotation of superstructure by live load and temperature changes, because they are expected to own functions to absorb relative displacement of superstructure and substructure. Bridge design is based on whole analysis models, which the bearing functions above are reflected. If bearing functions are declined, it is possible for structure of the whole bridge to be changed and have an 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) as a standard method for a bridge bearing inspection, “Visual inspection” is indicated, as well as “Measuring displacement” is indicated as an example, if necessary. However, it is difficult to evaluate the degree of deterioration of the bearing function in the visual inspection only. Therefore, it is not easy to evaluate deterioration degree of bearing function; moreover, any evaluation method by “Measuring displacement” has not been established.
Considering these points, we studied qualitative evaluation method of basic functions (load supporting, horizontal moving and rotating functions) for bridge bearings as structural members based on measuring displacement and strain.

In this study, as to steel bridges in service, displacement and strain measurement was conducted for the bearings, and deterioration level evaluation with proposing evaluation methods was attempted.

2 METHOD

2.1 *Evaluation Method*

We set evaluation methods required for bearings as structural members against basic functions for load supporting, horizontal moving and rotation functions each. We measured vertical and horizontal displacement of bearing, and evaluated deterioration degree of bearings with temporal transition of the displacement. Table-1 shows details of the evaluation methods and measuring items. In addition, in order to examine effects of bearing function deterioration against the girder, we also measured strain of the girder lower flange.

2.2 *Measuring Method*

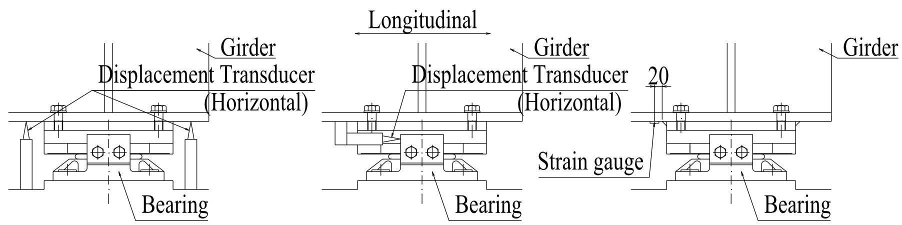
Figure 1 shows measuring places of displacement and deformation. We measured by the two conditions, short-term measurement focusing on live load and long-term measurement focusing on temperature changes. Table-2 shows the measuring time and frequency

2.3 *Measuring Object*

Table 3 shows measuring objects, the four bridges with different bearing types. All of the bearings were evaluated as sound by visual inspection that no corrosion and cracks were recognized.

Table 1. Measuring Method and Item for Bearing Function

Basic function required as a bearing	Measuring method	Measuring item
Load supporting function	Checking if vertical supporting function is impaired, and the entire bearing is moved up and down	Vertical displacement occurred in the front and back of the longitudinal direction
Rotation function	Checking if the bearing can follow rotation from girder deformation by live load	Vertical displacement occurred in the front and back of the longitudinal direction
Horizontal moving function	Checking if the bearing can follow girder movement by live load and girder expansion by temperature changes	Horizontal relative displacement in the longitudinal direction of superstructure and substructure
Effect against girder	Checking if there is large stress fluctuation occurred by bearing function deterioration	Stress fluctuation of the girder lower flange bottom located 20mm from weld toes of the sole plate front in the longitudinal direction



(a) Vertical displacement (b) Horizontal displacement (c) Girder deformation

Figure 1. Measuring location

Table 2.Measuring time and frequency

	Focus	Measuring time	Frequency
Short-term measuring	Live load	20min	200Hz
Long-term measuring	Temperature	1day	0.5Hz

Table 3. Detailed information for object bridge

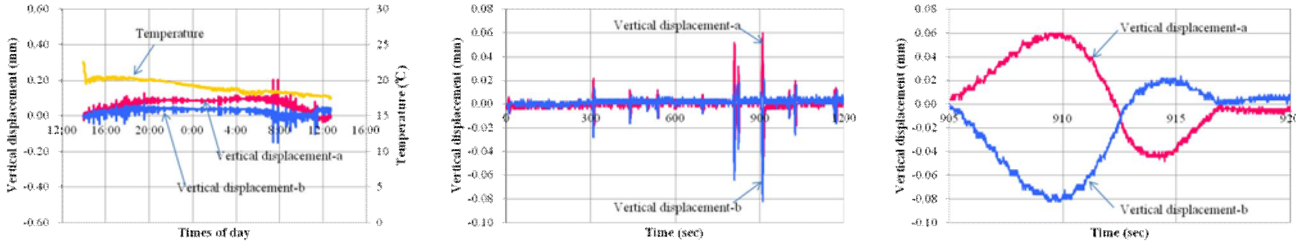
	Bearing type	Span length (m)	Horizontal alignment (m)	Installation year (year)	Traffic (No.of vehicles / day)
Bridge A	Bearing plate bearing	30.00	R=35	1986	21,179
Bridge B	Pin roller bearing	48.20	R=∞	1971*2	49,031
Bridge C	Pivot roller bearing	90.35	R=∞	1996	31,447
Bridge D	Rubber bearing	202.65*1	R=∞	2006	85,684

*1: Showing bridge length *2: Bearing replacement time is unknown.

3 RESULTS AND CONSIDERATION

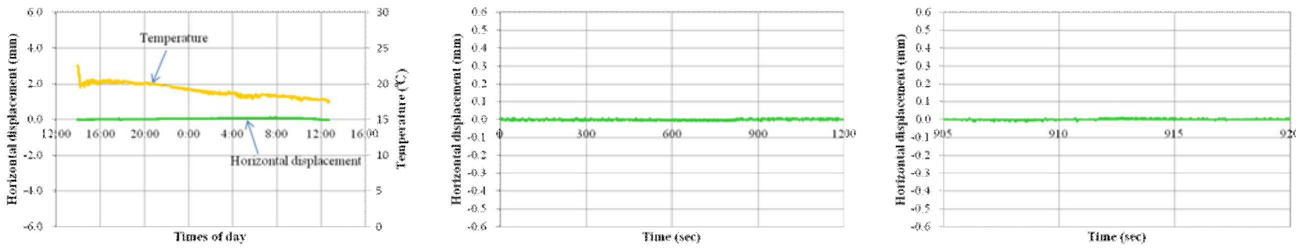
3.1 *Bearing Plate Bearing*

From Figure-2 to Figure-4, measuring results of Bridge A with bearing plate bearings are shown. Due to that vertical displacement was occurred in the upper and lower opposite direction in the front and back of the bearings, the bearing followed rotation by live load and temperature changes in short-term and long-term measuring. Meanwhile horizontal displacement was occurred in neither short-term nor long-term measuring, the bearing did not follow horizontal moving by live load and temperature changes. It indicates that the bearing horizontal moving function does not follow complex behavior of superstructure by small horizontal alignment of curvature radius. Moreover, when vertical displacement is occurred, horizontal displacement is not occurred as well as stress variation is occurred in the girder lower flange, thus we considered that the horizontal moving function has some issues.



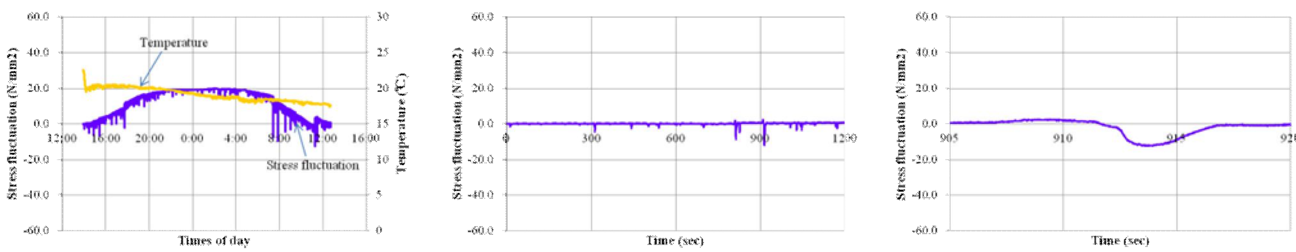
(a) Long-term measuring result (1 day) (b) Short-term measuring result (20 min.) (c) Short-term measuring result (15 sec. extracted)

Figure 2. Bearing plate bearing-vertical displacement measuring result



(a) Long-term measuring result (1 day) (b) Short-term measuring result (20 min.) (c) Short-term measuring result (15 sec. extracted)

Figure 3. Bearing plate bearing-horizontal displacement measuring result

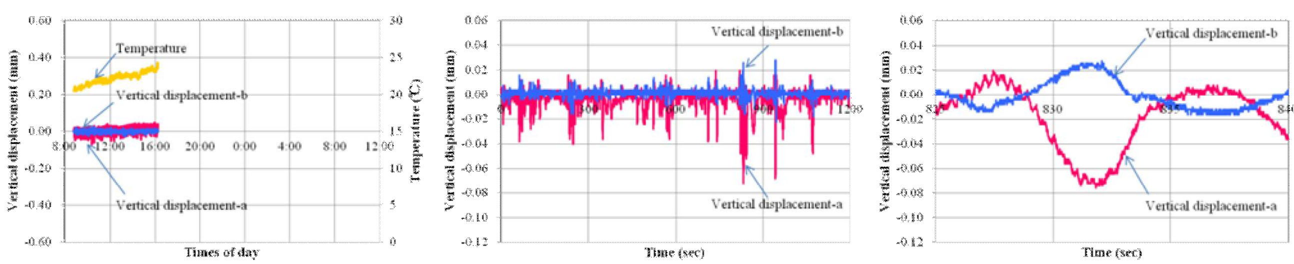


(a) Long-term measuring result (1 day) (b) Short-term measuring result (20 min.) (c) Short-term measuring result (15 sec. extracted)

Figure 4. Bearing plate bearing -lower flange stress fluctuation measuring result

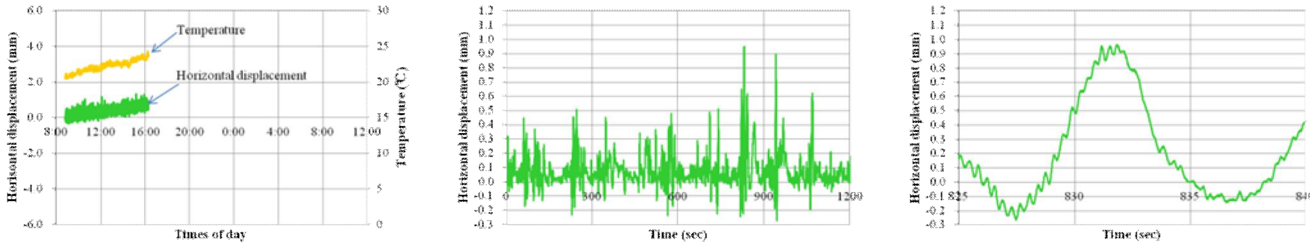
3.2 *Pin Roller Bearing*

From Figure-5 to Figure-7, measuring results of Bridge B with pin roller bearings are shown. Due to that vertical displacement was occurred in the upper and lower opposite direction in the front and back of the bearings, the bearings followed rotation by live load and temperature changes. While the bearings followed movement from live load temperature changes, due to that horizontal displacement was also occurred in the both short-term and long-term measuring. In addition, when rotation and movement was occurred, stress fluctuation was scarcely occurred. Thus, we considered that the rotation and horizontal moving function are not far problem.



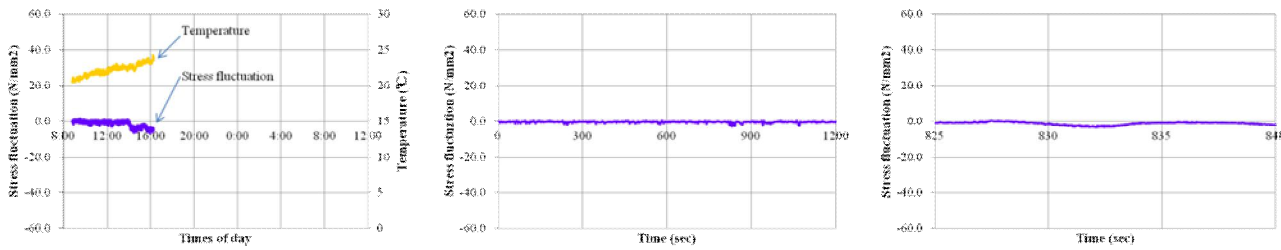
(a) Long-term measuring result (1 day) (b) Short-term measuring result (20 min.) (c) Short-term measuring result (15 sec. extracted)

Figure 5. Pin roller bearing-vertical displacement measuring result



(a) Long-term measuring result (1 day) (b) Short-term measuring result (20 min.) (c) Short-term measuring result (15 sec. extracted)

Figure 6. Pin roller bearing-horizontal displacement measuring result

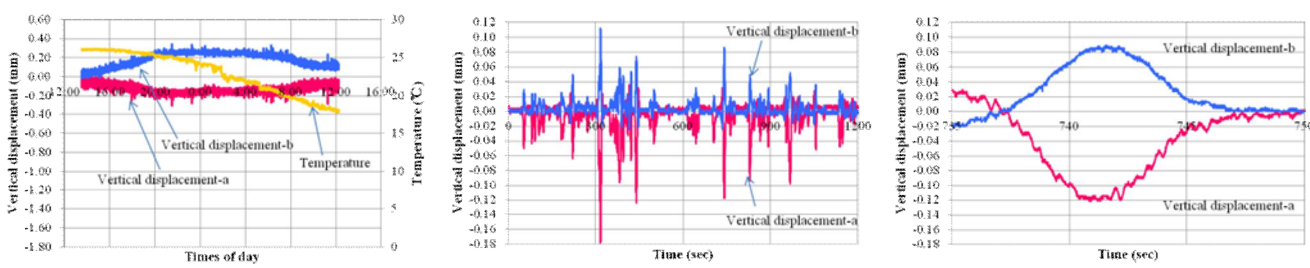


(a) Long-term measuring result (1 day) (b) Short-term measuring result (20 min.) (c) Short-term measuring result (15 sec. extracted)

Figure 7. Pin roller bearing -lower flange stress fluctuation measuring result

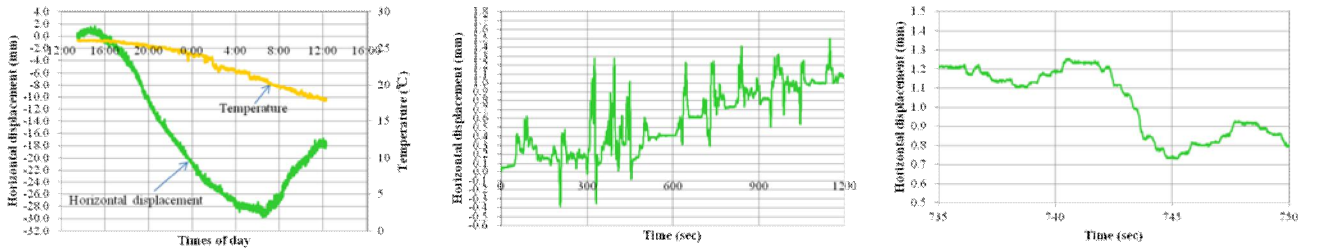
3.3 *Pivot Roller Bearing*

From Figure-8 to Figure-10, measuring results of Bridge C with pivot roller bearings are shown. Due to that vertical displacement was occurred in the upper and lower opposite direction in the front and back of the bearings, the bearings followed rotation by live load and temperature changes. While the bearings followed movement from live load temperature changes, due to that horizontal displacement was also occurred in the both short-term and long-term measuring. In addition, when rotation and movement was occurred, stress fluctuation was scarcely occurred. Thus, we considered that the rotation and horizontal moving function are not far problem as well as pin roller bearings.

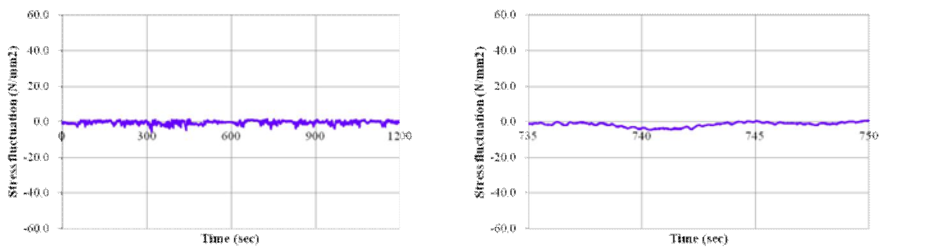


(a) Long-term measuring result (1 day) (b) Short-term measuring result (20 min.) (c) Short-term measuring result (15 sec. extracted)

Figure 8. Pivot roller bearing-vertical displacement measuring result



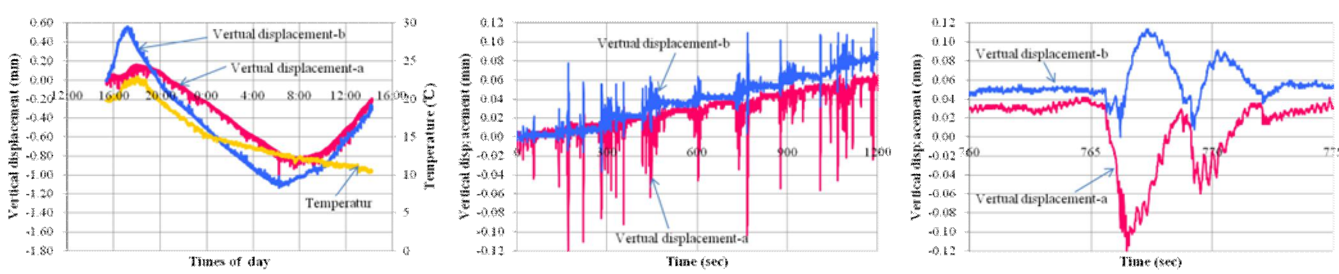
(a) Long-term measuring result (1 day) (b) Short-term measuring result (20 min.) (c) Short-term measuring result (15 sec. extracted)
Figure 9. Pivot roller bearing-horizontal displacement measuring result



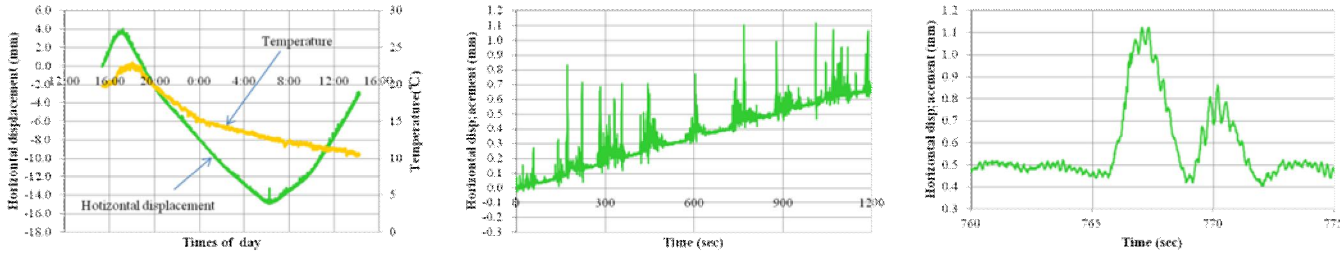
(b) Short-term measuring result (20 min.) (c) Short-term measuring result (15 sec. extracted)
Figure 10. Pivot roller bearing -lower flange stress fluctuation measuring result

3.4 *Rubber Bearing*

From Figure-11 to Figure-13, measuring results of Bridge D with rubber bearings are shown. Due to that upward vertical displacement was occurred with the temperature rise, and downward vertical displacement was occurred with the temperature falling, we considered that rubber bearing is expanded and contracted with the temperature changes. According to the short-term measuring results (15 sec. extracted), from the fact that downward displacement was occurred in the front and the back of the bearing, the bearing sinkage was occurred by live load. Further the bearing followed the rotation by live load, due to that displacement was different in the front and the back of the bearing. Due to that stress fluctuation was occurred when rotation and horizontal movement was occurred in the both of the short-term and long-term measuring results, it is shown that rubber bearing does not completely follow superstructure behavior.

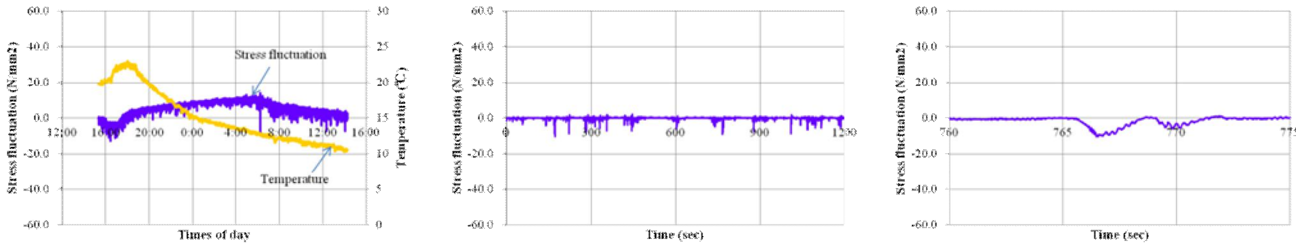


(a) Long-term measuring result (1 day) (b) Short-term measuring result (20 min.) (c) Short-term measuring result (15 sec. extracted)
Figure 11. Rubber bearing-vertical displacement measuring result



(a) Long-term measuring result (1 day) (b) Short-term measuring result (20 min.) (c) Short-term measuring result (15 sec. extracted)

Figure 12. Rubber bearing-horizontal displacement measuring result

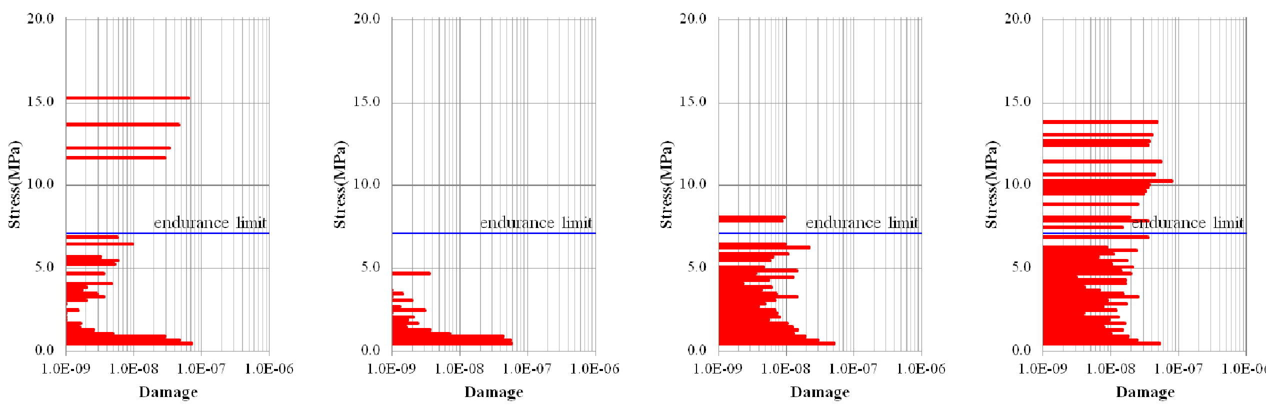


(a) Long-term measuring result (1 day) (b) Short-term measuring result (20 min.) (c) Short-term measuring result (15 sec. extracted)

Figure 13. Rubber bearing -lower flange stress fluctuation measuring result

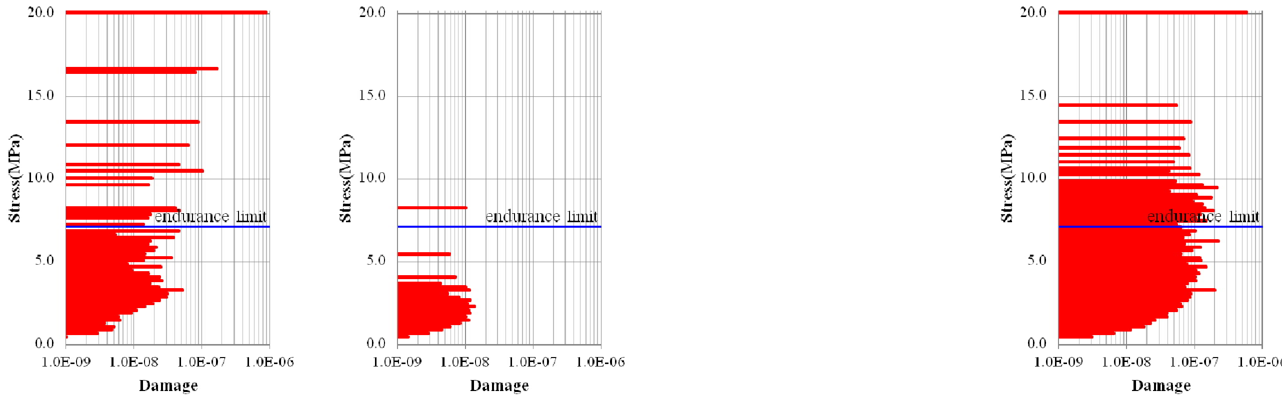
3.5 *Bearing Behavior Verification and Function Evaluation from Measuring Results*

We calculated fatigue life based on stress fluctuation of the girder lower flange, and examined the correlation between the fatigue life and the bearing function evaluation above described. Fatigue curve used for fatigue life calculation was the curve, which was the lowest H' class among the reference Japanese society of steel construction, 2012). It was used for the study, and 7 MPa was endurance limit. Moreover, to calculate the frequency distribution of the stress range, we used the general method "rainflow-counting method". In addition, each parameters by structure details shall not be considered.



(a) Bearing plate bearing (b) Pin roller bearing (c) Pivot roller bearing (d) Rubber bearing

Figure 14. Stress amplitude - damage level graph for each bearing (20 min.)



(a) Bearing plate bearing (b) Pin roller bearing (d) Rubber bearing

Figure 15. Stress amplitude - damage level graph for each bearing (1 day)

Table 4.Bearing function evaluation and fatigue life

	Large vehicle traffic (no. of vehicles / day)	Function evaluation from measuring results		Fatigue life			
				Short-term measuring		Long-term measuring	
		Rotation function	Horizontal moving function	Fatigue life (year)	Relative ratio	Fatigue life (year)	Relative ratio
Bearing plate bearing	4,294	Rotating	Not moving	233	3.3	1,691	2.0
Pin roller bearing		Rotating	Moving	∞	∞	83,534	96.7
Pivot roller bearing	11,576	Rotating	Moving	2,218	31.2	-	-
Rubber bearing	7,800	Rotating	Moving	71	1.0	864	1.0

The steel bearings, which follow rotation and horizontal movement with their different parts, and the rubber bearings, which follow rotation and horizontal movement with the same parts, are considered separately. As to correlation between moving function and fatigue life, fatigue life of Pin roller and Pivot roller bearings that move is relatively long, whereas fatigue life of bearing plate bearing that does not move at all was short. Thus, we found tendency that fatigue life becomes shorter when moving function becomes lower.

While fatigue life of Rubber bearing is relatively short, although it has moving functions. We consider that constant spring stiffness of Rubber bearing generates resistance force against movement of superstructure as one of the reasons. Moreover, why fatigue life of Rubber bearing that moves is shorter than bearing plate bearing that does not move at all is also large vehicle traffic of the bridges heavy. In spite of that bearings have moving function, fatigue life become sometimes relatively shorter.

4 CONCLUSIONS

As the measurement result of displacement and strain of the girder lower flange for bearings of steel bridges in service with functional evaluation methods, the following knowledge was gained.

i. As measuring vertical and horizontal displacement for one day, evaluation of rotation and horizontal moving function against temperature changes becomes possible.

ii. As measuring vertical and horizontal displacement for 20 minutes, evaluation of rotation and horizontal moving functions against live load becomes possible.

iii. When rotation and horizontal movement is occurred by live load, rotation and movement by temperature changes is also occurred. Meanwhile, in this measuring, when rotation and horizontal movement by live load was not occurred, rotation and movement by temperature changes was not occurred, either.

iv. Stress fluctuation is occurred in the girder lower flange, even if rotation and horizontal movement is occurred. Therefore in case of that bridges have heavy large vehicle traffic and concerns of fatigue damages, it is necessary to measure stress fluctuation of the girder lower flange in addition to vertical and horizontal displacement.

From the above, it was verified that effectiveness of the bearing function evaluation methods in the study. In order to establish more precise and practical function evaluation methods, it is preferable to have further results of measuring.

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