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Field Measurement of a Steel Railway Bridge with Rubber Bearings

Mesures sur des ponts ferroviaires métalliques avec appuis en caoutchouc

Vermessungen einer Stahleisenbahnbrücke mit Gummilagern

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SUMMARY

There are many instances of metallic bearings used in steel railway bridges being deformed. The authors want to make use of the advantage of rubber bearings which reduce the load imposed on the top of an abutment or a pier. This paper reports on the results of measurement of a steel railway bridge with rubber bearings under a long-term use.

RÉSUMÉ

De nombreux cas de déformation d'appuis métalliques sont constatés dans les ponts ferroviaires métalliques. Les auteurs veulent profiter des avantages d'appuis en caoutchouc qui exercent moins de charge sur la tête de la culée ou de la pile. L'article décrit le résultat de mesures effectuées pendant une longue période sur des appuis en caoutchouc de ponts ferroviaires.

ZUSAMMENFASSUNG

Es gibt viele Schäden an den Stahllagern von Eisenbahnbrücken, die sich deformieren. Die Autoren wollen deshalb den Vorteil von Gummilagern nutzen, weil das Gummilager die Lageroberfläche weniger belastet. Es wird berichtet über die Messresultate einer Eisenbahnbrücke aus Stahl mit Gummilagern nach Langzeitgebrauch.

1. INTRODUCTION

We carried out a measurement at the support to Tokyo (the fixed side), of Minami-Senju Anti-Overflow Bridge (Overbridge) on Joban-Up Line described in Document [1], as a follow-up survey. This bridge is a deck plate girder, measuring 6m span length, for about 10 years in service. The rubber bearings have been laid was erected, but the sole plate is not set up especially. The measured position is shown in Figure 1 and the content of the measurement at each point of measurement is shown in Table 1.

Moreover the fatigue test of rubber bearings prior to the application to the bridge was carried out. Rubber bearrings' fatigue due to the horizontal shearing deformation and the vertical deformation under 2,000,000 cycles of loading was investigated under the condition assumed to occur when they were used for the steel railway bridge. The rubber bearings are judged to be fit for practical use in terms of the support and the fatigue durability performance from this examination result.

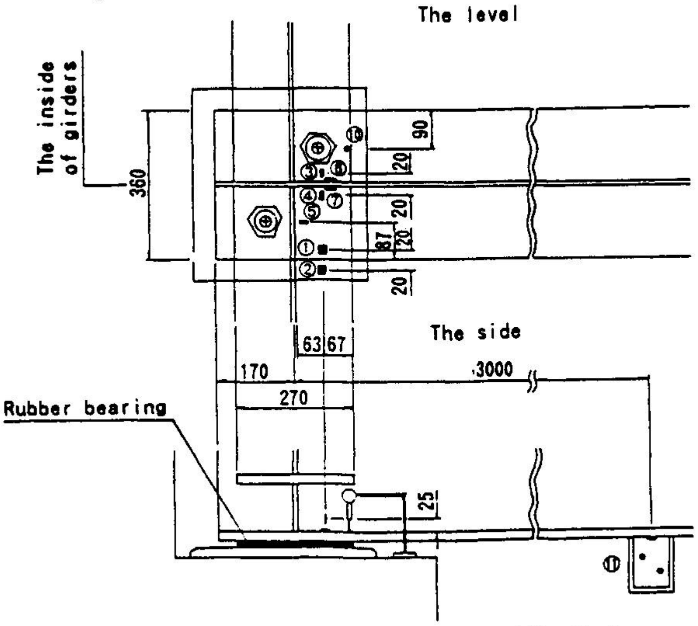

Figure 1 Measurement position (①-⑪ in figure corresponds to No. in Table 1)

Table 1 Content of measurement

No	Sort of gauge etc.	Measured position	Measured items
①	accelerometer (10G)	on the lower flange at the support in a main girder	characteristic of vibration
②	accelerometer (5G)	on the top mortar of an abutment	characteristic of vibration
③	gauge of single axis	on the lower flange at the support in a main girder (the right angle direction to a main girder, the inside of girders)	local stress
④	gauge of single axis	on the lower flange at the support in a main girder (the right angle direction to a main girder, the outside of girders)	local stress
⑤	gauge of single axis	on the lower flange at the support in a main girder (the direction of a main girder, the outside of girders)	local stress
⑥	gauge of single axis	at bottom of the web at the support in a main girder (the inside of girders)	local stress
⑦	gauge of single axis	at bottom of the web at the support in a main girder (the outside of girders)	local stress
⑩	dial gauge	on the lower flange at the support in a main girder	train's running stability and riding comfort under deflection
⑪	non-contact displacement gauge	the deflection of a main girder at the span center	train's running stability and riding comfort under subsidence

2. RUBBER BEARING'S STRUCTURE AND MATERIALS

The rubber bearing which is used in a steel railway bridge has stainless steel plates on both faces of chloroprene rubber 8mm-16mm thick. The number of heavy layers of rubber bearings is three.
Moreover, rubber used for the rubber bearing is high-quality chloroprene rubber which excels in the low temperature characteristic and meeting the standard shown in Table 2 of C08-b1 of JIS K 6386 (Rubber Materials for Vibration Isolators).

Table 2 Rubber's quality standard

Physical characteristic		Unit	Standard value
static shear modulus of rigidity		kgf/cm²	8±1.0
hardness			50±5
elongation		%	over 400
oil resistivity (transition modulus of volume)		%	under +120
aging resistivity	transition modulus of 25% elongation stress	%	-10-+100
	transition modulus of elongation	%	over -50
strain modulus of compression permanence		%	under 35
ozone resistivity			no crack to the naked eye's observation
coldness resistivity		℃	under -40

3. THE EQUIPMENT USED FOR THIS MEASUREMENT AND ANALYSIS

A bridge diagnosis system (BMC system) was used in the measurement and the analysis. This system is the one that integrates the bridge's maintenance which was implemented in the field by practiced inspectors so far. It is devised to operate easily, and has the function to do another real bridge measurement, its soundness diagnosis, and various analyses concerning the structure efficiently.
Moreover a non-contact displacement gauge was used for the measurement of the deflection of the span center of a main girder. This has the characteristic to be able to measure a bridge even over the road where traffic is heavy and the river, and able to measure the roll besides the deflection, unlike the old ring type deflectometer.

4. RESULTS OF EXAMINATION

4.1 The Effect of Reducing Vibration at a Support

4.1.1 Examination by Accelerations

The decrease degree of a vertical acceleration on the lower flange at the support in a main girder and on the top mortar of an abutment was investigated. The measuring trains are No.1-No.7 of Table 3 and an acceleration wave form of train No.6 is illustrated in Figure 2 and Figure 3. The peak appears at several places, and we think this is the influence of impact of wheel flats and the like. Table 4 shows the comparison between the measured results of this examination and Document [1] . It can be said that the anti-vibration effect is evident th ough there are some variations in the maximum vertical acceleration and in the decrease degree of the acceleration on the lower flange at the support in a main girder and on the top mortar of an abutment.

4.1.2 Frequency Analysis

The shape of vertical acceleration waves were spectrum-analyzed (Fourier-transformed) and frequency-analyzed by the BMC system. The case of train No.6 is shown as one example. Figure 4 shows frequency analysis of a vertical acceleration on the lower flange at the support in a main girder. The power spectral density is generally high at each frequency and the dominant frequency does not appear clearly. On the other hand, Figure 5 shows frequency analysis of a vertical acceleration on the top mortar of an abutment. The dominant frequency appears remarkably and power spectral densities of other frequencies are values closest to 0. As a result, it is understood that the frequency elements other than the dominant frequency have been cut through the rubber bearing when the vibration is transmitted from the lower flange to the top of an abutment. It can be said from the thing that the effect of reducing the vibration is evident.
The dominant frequency at the support happened to be different in the values by trains, being 30Hz-77Hz. These values are alm ost the same values on the lower flange and on the top of an abutment.

Table 3 Measuring trains

No	Sort of train	the number of cars	speed (km/h)
1	local electric train	10	53
2	limited express electric train	7	55
3	limited express electric train	11	62
4	local electric train	7	44
5	local electric train	10	51
6	limited express electric train	7	55
7	limited express electric train	11	75
8	local electric train	10	30
9	local electric train	10	30
10	local electric train	11	22
11	local electric train	15	38
12	limited express electric train	11	39
13	local electric train	10	32
14	limited express electric train	7	62

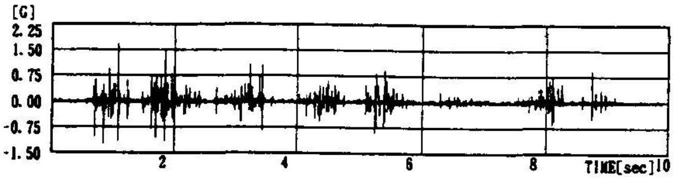

Figure 2 The wave forms of vertical acceleration on the lower flange at the support

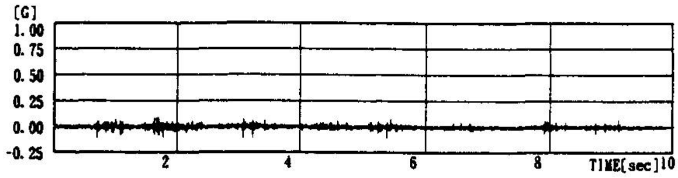

Figure 3 The wave forms of vertical acceleration on the top mortar of an abutment

4.2 The Evaluation of Train's Running Stability and Riding Comfort

Because the deflection of a girder, the unevenness, etc., have been taken as indexes of train's running stability and riding comfort so far, the evaluations were done hereaccording to these indexes, too.

4.2.1 The Deflection at the Span Center

Table 4 Measured result (acceleration)

Category	This examination (7 trains)	Document[1] (4trains)
the maximum vertical acceleration on the lower flange at the support in a main girder	0.3G-1.8G	0.7G-2.7G
the maximum vertical acceleration on the top mortar of an abutment	0.04G-0.2G	0.10G-0.2G
the decrease degree of the acceleration	7.5G-17.0G	6.6G-22.4G

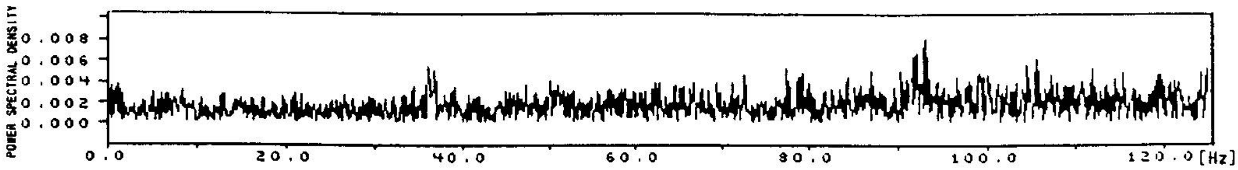

Figure 4 Frequency analysis of vertical acceleration on the lower flange at the support

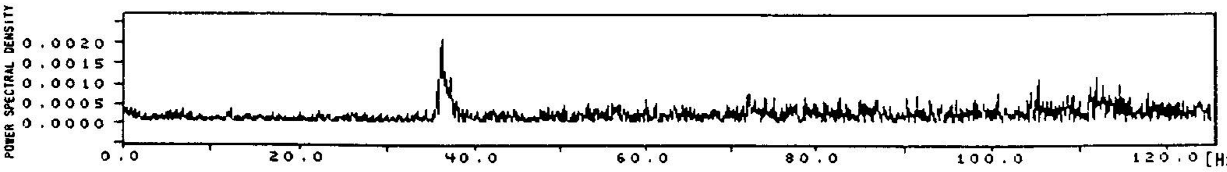

Figure 5 Frequency analysis of vertical acceleration on the top mortar of an abutment

Measuring trains for the deflection of a main girder at the span center are four (No. 10 and No. 12-No. 14 of Table 3), and the measured result including Document [1] is shown in Table 5. Both can be said to differ little. The wave forms by train No. 14 are shown in Figure 6 as one example. Moreover, because the values contain the subsidence and the impact value at the support due to rubber bearing's elastic deformation, and moreover, they are far smaller than deflection's limit value L/800 of a main girder, there will be no problem.

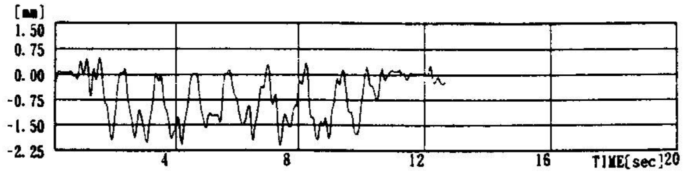

Figure 6 The wave forms of deflection at the span center

4. 2. 2 The Vertical Unevenness at The Support

The subsidence shown in Table 5 was caused at a support in a main girder (the case of train No. 14 is shown in Figure 7 as an example of the wave form). Because the value is much smaller than deflection's limit value 4mm at a crossing both at an end floor beam and an end stringer laid down empirically as the index of train's running stability and riding comfort, when a train goes from an abutment into a bridge and goes out of it, this is not a value nothing any problem, either.

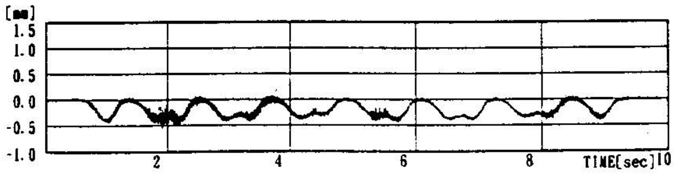

Figure 7 The wave forms of subsidence at a support

Table 5 Measured result (deflection and subsidence)

Category	This examination (4 trains)	Document[1] (4trains)
the deflection of a main girder at the span center	2. 0mm-2. 6mm	1. 9mm-3. 0mm
the subsidence at a support in a main girder	0. 3mm-0. 6mm	———

4. 3 The Evaluation of Local Stress and Fatigue at a Support

4. 3. 1 Local Stress at a Support

Measuring trains to examine the local stress of the support were seven, that is, No. 8-No. 14 of Tables 3. Being local stresses, the maximum amplitude stresses were as small as 10MPa-25MPa though wave forms were different by measured points.

4.3.2 Evaluation by Fatigue Damage Degere

Fatigue damage degree at bottom of web plate at a support was calculated by BMC system. Here the fatigue damage degree is the fatigue degree when one train has passed, and when the accumulation reaches 1, fatigue damage will be caused to the joint concerned. The stress range which had been used to calculate was assumed to be the stress range generated in the direction of steel plate surface whose value was larger than the bending stress range generated in the right angle direction to steel plate surface (it was calculated from strain gauge of single axis pasted to inside and outside across web plate by BMC system). The welded joint at the bottom of web was assumed that 2000000 cycles basic allowable fatigue stress range was $\Delta\sigma_{f0}$=80MPa (there was full penetration welded joint at bottom of the web, and the fillet welded joint of the load-non-transmitted and non-finish type was assumed). In one example of measurement by train No.14, fatgue damage degree was D_0=0.023*10^{-6}, which means that the first fatigue damage to the welded joint at the bottom of lower flange comes after about 40,000,000 times of the train passage. Therefore it is understood that there is considerable reserve of strength.

4.3.3 Revision of Sole Plate Standard Thickness

Accordingly, it has been understood that there are not any problems concerning the local stress, at the support even when there is no sole plate like this bridge. However, because reaction in the support may not be distributed easily and equally, and dust may collect easily with possible corrosion, and so on, in the vicinity of a bearing, it is decided to revise the standard such that the sole plate is set more than 22 mm in thickness as in the case of general bearings. In general, the sole plate is more often set 28 mm in thickness because the plate is gouged and it is fastened with high strength bolts.

5. CONCLUSIONS

To sum up to results :

(1) As a result of measuring the vibration of the support, it has been understood that the effect of reducing the vibration is retained as well as immediately after this bridge was erected. The same can be said from the frequency analysis result.

(2) As a result of examination, it has been understood that running stability and riding comfort are retained as good as immediately after the bridge was erected, with no problem about the value obtained.

(3) Because, in this bridge which did not use the sole plate, it has been understood that there is no problem about the local stress and fatigue at the support, the sole plate thickness is held same as in general bearings. Moreover, the standard is revised to specify hot dip galvanizings of zinc as anti-rust protection of the sole plate.

According to the result, rubber bearing's utility, and especially its performance sometime after being erected, was able to be confirmed. Future policy will be to adopt the rubber bearing for a steel railway bridge more aggressively than before.

ACKNOWLEDGMENT

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REFERENCE DOCUMENTS

[1] Ichikawa, A., Taketomo, N. : Examination of Rubber Bearings for a Steel Girder, Structural Designing Data, No.75, 1983 (in Japanese).