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Vibration Control of Stiffening Arch Bridge

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A variety of technical problems related to highway bridges have been pointed out, because an increasing number of heavy trucks are seen on nation's highway in recent years, and the method of reinforcement of bridges has become the center of wide interest. In the reinforcement of bridges, it is necessary to consider the serviceability of bridges not only in terms of statistical and dynamical problems, but also the vibration felt by pedestrians.

In this paper, a particular stiffening arch bridge (Lohse girder bridge), which holds these problems described above, is considered as case study. The method of reinforcement is investigated by the insertion of diagonal hangers. In order to find out the most efficient of reinforcement on this bridge, a statistical inference method (a design of experiments) is applied to this study. In this method, the evaluation of vibration control is investigated. It is considered that the acceleration corresponds to the magnitude of vibration on the bridge and the velocity corresponds to the vibration felt by a pedestrian. Each effective value of the response acceleration and velocity is calculated by dynamic analysis of nonstationary response of the bridge with inserted diagonal hangers under a moving heavy vehicle, and the optimum combination of diagonal hangers is estimated from these effective values. The effect of insertion of the estimated optimum combination on the serviceability of this bridge based on the vibration sensibility of pedestrian, and the statistical and dynamic problems is investigated.

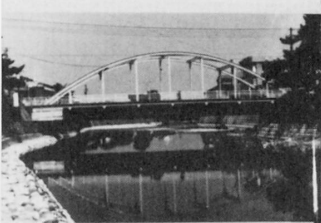
Using the calculated results described above, and taking aesthetic point into consideration, actual construction was done to reinforce the bridge. Before and after testing was done to determine the effect of the insertion of the diagonal hangers. From the measured results of this field test, it could be seen that these results bore out the predictions of the analytical study.

The major conclusions of this study can be summarized as follows:

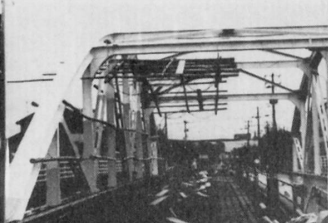
- (1) The load carrying capacity of the stiffening girder increases because the applied load is dispersed by these diagonal hangers.
- (2) The excitation of the first asymmetric vibration is eliminated because the vibration mode is changed by the alteration of the bridge structure system and the natural frequency increases.
- (3) The serviceability of this bridge is improved because the vibration felt by the pedestrian decreases.

Finally, from the results of this analytical study and field test, it is recognized that the method of reinforcement using diagonal hangers is a successful way for vibration control in the stiffening arch bridge.

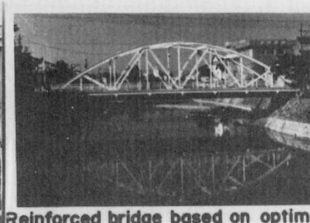
VIBRATION CONTROL OF STIFFENING ARCH BRIDGE



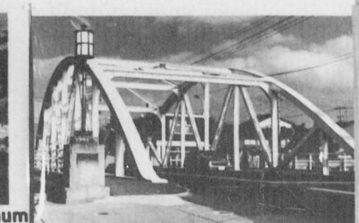
Scenery of NAKAJIMA bridge (it was constructed at 1955).



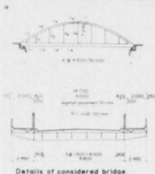
Construction for reinforcement.



Reinforced bridge based on optimum combination of diagonal hangers.



Reinforced bridge based on optimum combination of diagonal hangers.



Orthogonal array table (L16, 3, 2, 2) and plan of factors.

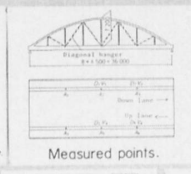
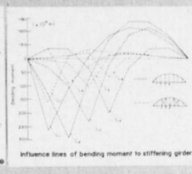
Run	Factor 1	Factor 2	Factor 3	Factor 4
1	1	1	1	1
2	1	1	2	2
3	1	2	1	1
4	1	2	2	2
5	2	1	1	1
6	2	1	2	2
7	2	2	1	1
8	2	2	2	2
9	3	1	1	1
10	3	1	2	2
11	3	2	1	1
12	3	2	2	2
13	4	1	1	1
14	4	1	2	2
15	4	2	1	1
16	4	2	2	2

Vehicle load and roadway properties.

Span length	120 m
Number of spans	2
Width of roadway	12 m
Grade	0%
Design speed	100 km/h
Design load	HT-100
Design wind speed	20 m/s
Design earthquake	Level 2
Design temperature	±30°C
Design corrosion	Level 3

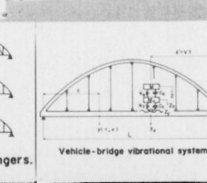
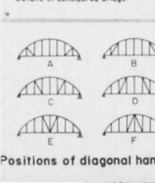
Results of analysis of variance.

Factor	Sum of squares	F-value	P-value
Factor 1	1500	15.0	0.0001
Factor 2	800	8.0	0.0010
Factor 3	200	2.0	0.1000
Factor 4	100	1.0	0.3000
Error	1000	-	-



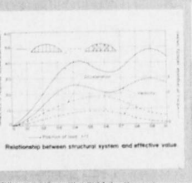
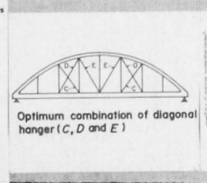
Results of field test.

Location	Frequency	Amplitude
1	1.2 Hz	0.5 mm
2	1.5 Hz	0.8 mm
3	2.0 Hz	1.2 mm
4	2.5 Hz	1.5 mm
5	3.0 Hz	1.8 mm



Natural frequencies and effective values on treatment conditions.

Mode	Frequency (Hz)	Effective Value
1	1.2	0.5
2	1.5	0.8
3	2.0	1.2
4	2.5	1.5
5	3.0	1.8
6	3.5	2.0
7	4.0	2.2
8	4.5	2.4
9	5.0	2.6
10	5.5	2.8



Results of field test.

Location	Frequency	Amplitude
1	1.2 Hz	0.5 mm
2	1.5 Hz	0.8 mm
3	2.0 Hz	1.2 mm
4	2.5 Hz	1.5 mm
5	3.0 Hz	1.8 mm
6	3.5 Hz	2.0 mm
7	4.0 Hz	2.2 mm
8	4.5 Hz	2.4 mm
9	5.0 Hz	2.6 mm
10	5.5 Hz	2.8 mm