Measurement of the Stress and Deflection of Kanzaki Bridge

By

Masao NARUOKA

Department of Civil Engineering

(Received February 1954)

1. Introduction

The Kanzaki Bridge is the first composite beam bridge in Japan.

The author measured the live load static stress and deflection of this bridge built up of five main beams and a report of the results will be given in the following.

The object of this load test is to make clear the difference between a single beam and parallel beam structure composing a bridge. When there is a number of parallel beams, a load on a certain main beam is not carried by that beam alone, but all the beams which are connected together by reinforced concrete slab, lateral bracings and cross frames cooperate and carry a certain percentage of the load. As this idea of the cooperation of the main beams is not introduced in the conventional method of design calculation, a comparison will be made between the conventional method and the new method considering the cooperation of beams, taking the measured values of the Kanzaki Bridge as an example.

2. Measurement

The strain was measured with the electric resistance wire strain gages, Baldwin SR-4 Strain Indicator and 12 Channels Switching and Balancing Unit and the deflection with the dial gages. The strain and deflection were measured at the middle section of the second span from the right hand side. Two 16 t trucks were loaded at various positions as static live load.

Details of the tested span are shown in Figs.

3. Results and Discussion of the Measured Values

1) Stress

The result of the measured values of the stress is given in Table 1. The table shows the value of stress ratio (measured stress/calculated stress).

The values obtained by taking the stress calculated with the conventional method

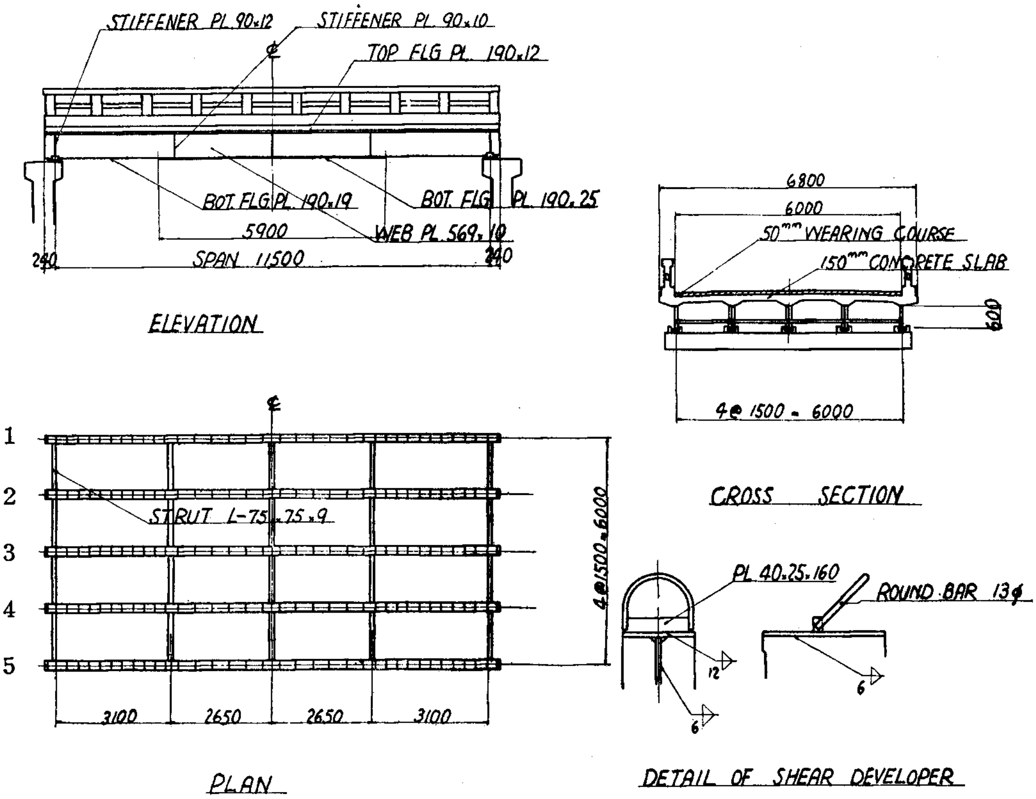

Fig. 1 Details of the Tested Span.

Table 1. Stress Ratio (%)

State of loading	1				2		3			4		5			6	
Method of calculation	A	B	C	D	A	B	A	B	D	A	B	A	B	D	A	B
main beam 1	74	61	65	54	70	65	110	56	56	108	49	∞	68	81	∞	90
main beam 2	74	65	66	66	79	69	44	52	55	52	56	50	53	64	46	55
main beam 3	46	67	83	73	45	65	38	61	71	38	59	53	58	77	56	67
main beam 4	72	64	66	65			∞	67	74	∞	58	49	52	66	45	53
main beam 5	72	59	65	53								∞	61	90	∞	90

Note: A: conventional method of calculation,
B: method of calculation by the theory of continuous slab supported by elastic beams,
C: approximate method of calculation of the distribution of wheel load due to the slab,
D: method of calculation by the theory of orthogonal anisotropic plate.
∞ in column A means that the calculated value corresponding to the measured value is zero.

as the denominator are given in column A and those obtained by taking the stress calculated with the method of considering the distribution of the load to all beams by the theory of the continuous slab supported by elastic beams[1] (this theory is briefly called the theory of continuous slab in the following) are given in column B.

In the calculation of load distribution to all beams by the theory of continuous slab, the following values are used.

$$H = EI/Nl = 8.12\,,$$
$$a/l = 0.13\,,$$

where H=relative stiffness of beam, compared to that of the slab,

EI = flexural rigidity of beam = 2,626,000 kg. cm^2 (the width of compression flange is taken as 1.50 m and n as 10),

N = flexural rigidity of slab = 28,130 kg. cm (Poisson's ratio is taken as 0),

a = spacing of beams = 1.50 m,

l = span of bridge = 11.50 m.

This flexural rigidity of the beam is considered as being equal for all beams for the sake of convenience of calcuation.

As is clear from the table, the values of the stress ratio obtained by the conventional method are considerably scattered, but those by the theory of continuous slab are comparatively concentrated. As the stress ratio average in this case is about 66%, it can be said that this value is almost the same as the measured value of the highway bridge in Siegen, Germany, which is approximately 70%[2]. As this bridge is, however, a lattice composite beam structure, the value calculated as a lattice composite beam is adopted as the denominator of the stress ratio. This point differs slightly from the method of caluculation in this paper, which will be discussed later. The values calculated for the case of state of loading 1 by the approximate calculation method of the load distribution of wheel load due to the slab proposed by H. Omura are given in column C[3].

2) Deflection

The result of the measured deflection is given in Table 2. Similar to the case of the stress, the values are given as deflection ratio (measured deflection/calculated deflection). Three methods of calculation, the same as in the case of the stress, are adopted in calculating the values (C only for the case of state of loading 1). As is clear from Table 2, similar to the case of the stress ratio, these is a great difference in the values of the deflection ratio calculated by the conventional method according to the beam and state of loading, but the values obtained with the theory of continuous slab are all almost equal. The average of the deflection ratios, corresponding to 66% for the stress ratio, is about 80%.

Table 2. Deflection ratio (%)

State of loading	1				2		3			4		5			6	
Method of calculation	A	B	C	D	A	B	A	B	D	A	B	A	B	D	A	B
main beam 1	86	73	66	62	81	78	132	73	67	132	68	∞	97	88		
main beam 2	74	94	62	66	84	75	53	69	70	52	65	59	71	78	58	78
main beam 3	47	78	81	77	46	74	40	75	81	50	86	58	79	90	58	83
main beam 4	81	81	65	74	72	75	∞	89	89	∞	85	56	68	82	56	75
main beam 5	88	75	69	62	125	71						∞	92	92	∞	96

Note: The meaning of A~D & ∞ is the same as with the case of Table 1.

4. Comparison of the Ratios Obtained About Single Beam and Parallel Beam Structure

A load test on a single beam exactly the size of this beam bridge was performed by Y. Tachibana, Professor of the Osaka Municipal University, on April 26, 1953. According to this load test, the stress ratio and deflection ratio are 89% and 84% respectively under the design load of 18 t, while with parallel beams structure composing the actual bridge, the values are 66% and 80%. The values for the deflection are comparatively close, but for the stress the values differ considerably. It can be said that these points are the difference between the single beam and parallel beam structure.

5. Consideration of the Parallel Composite Beam Bridge as Orthogonal Anisotropic Plate

With bridges in which the comparatively small steel girder and the slab are made into one structure by shear connectors, as in the case with this bridge, it can be considered that the structure is converted to orthogonal anisotropic plate by reinforcing the concrete slab with the steel beam reinforcement. If the values of the stress and deflection are calculated and the stress ratio and deflection ratio obtained with this idea in mind, the results become as given in column D in Table 1 and 2[4]. Except for some exceptions the values are almost the same, showing that the method of calculation treating the structure as orthogonal anisotropic plate gives approximately accurate results. However, to decide which method of calculation is better, that by the theory of continuous slab or that by the theory of orthogonal anistotropic plate, must be judged by taking many measurements and discussing them theoretically.

6. Discussion on the Stress Ratio of Parallel Beam Structure

The stress ratio of this bridge is 66% while that of the lattice composite beam bridge in Siegen is 70%. Why does the stress ratio become small?

The above composite beam bridge on which K. Klöppel performed his experiment is a lattice beam bridge which has a cross beam at the center of the span for distributing the load. Thus the calculation for the lattice beam was done and then the calculation for the composite beam was done. K. Klöppel gave the following as the main reason for the stress ratio becoming small[2].

a) It is a mistake to assume that the load distributing beam is rigid.

b) The load distributing function of the reinforced concrete slab is neglected.

c) The torsional rigidity of the beams is neglected.

In the theory of continuous slab adopted in calculating this bridge, the load distributing action of the slab is considered as it is the main object, but the torsional rigidity of the beam is neglected. The load distributing action of the lateral bracings which connect the beams also can not be neglected. The slab is not of equal flexural rigidity, it being larger near the support than at the center. Also the slab is assumed as being supported linearly on the elastic beams, but it is supported on a certain width of the upper flange of steel girder. It is assumed that these factors accumulate and reach a value of about 30%. It is noteworthy, however, that the value of stress ratio is about 70%, even when it is calculated by a strict method.

7. Conclusion

Although this paper is only a discussion on the calculated and measured values of the live load static stress and deflection of the Kanzaki Bridge which is the first composite beam bridge in Japan, the following can be concluded.

a) The stress ratio is about 70%, even when the stress is calculated by a strict method. Judging from the measured value in a certain German bridge, it is believed that this value is almost correct. The deflection ratio is larger than this.

b) In comparing these ratios measured in a single beam with those in a parallel beam structure, both the stress ratio and the deflection ratio are smaller in the latter. This is due to the load distributing action of the slab to each beam.

c) The fact that the stress ratio is about 70% is due to the load distributing action of the slab, the torsional rigidity of the beam and the other incomputable factors.

d) Together with the reports on the measured dead load stress given lately[5], the fact that the live load static stress is comparatively small should be taken into consideration in the design of bridges in future.

Reference

1) M. Naruoka, Transaction of the Japan Society of Civil Engineers, No. 4 (1949), p. 1.
N. M. Newmark, University of Illinois Bulletin, No. 336 (1942).
2) K. Klöppel und E. Noske, Stahlbau, Bd. 21 (1952), S. 38.
3) H. Omura, Journal of the Japan Society of Civil Engineers, Vol. 39 (1954), No. 1, p. 43.
4) W. Cornelius, Stahlbau, Bd. 21 (1952), S. 21, 43 und 60.
5) Advance Report of Comittee 30 —Impact and Bridge Stresses, American Railway Engineering Association— Bulletin 509 (1953), p. 37.
L. T. Wyly, R. W. Kluge, K. H. Lenzen, L. B. McGammon, M. B. Lagaard, E. W. Larson, Proc. A. S. C. E., Vol. 79, Separate No. 219 (1953).