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Measurement of the Stress and Deflection of Kanzaki Bridge

Mesure des contraintes et des flèches sur le pont Kanzaki

Spannungs- und Dehnungsmessungen an der Kanzaki-Brücke

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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, which is built up of five main beams, and a report of the results is 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, the 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 electric resistance wire strain gages, Baldwin SR-4 Strain Indicator and 12 Channels Switching and Balancing Unit and the deflection with 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.

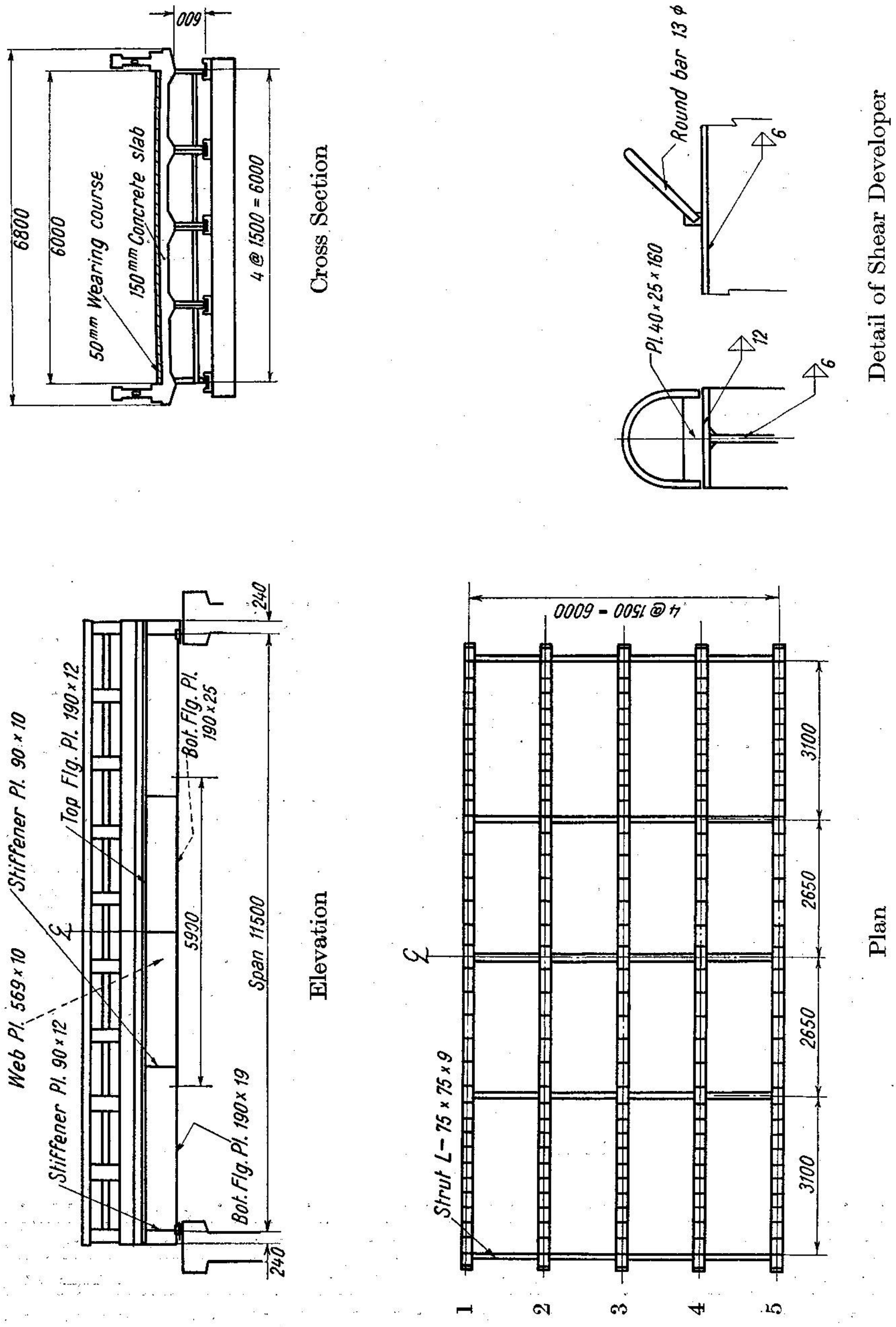

Fig. Detail of the tested span

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 as 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 (this theory is briefly called theory of continuous slab in the following) are given in column B.

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 the 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.

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 calculation.

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%. As this bridge is, however, a lattice composite beam structure, the value calculated as a lattice composite beam is adopted as denominator of the stress ratio. This point differs slightly from the method of calculation 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*.

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*, *B*, *C*, *D* and ∞ is the same as in the case of Table 1.

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, there 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 nearly equal. The average of the deflection ratios, corresponding to 66% for the stress ratio, is about 80%.

4. Comparison of Single Beam and Parallel Beam Structure

A load test on a single beam exactly the size of this beam bridge was carried out 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 beam 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. 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 anisotropic 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 made, and then the calculation for the composite beam was made. K. Klöppel gave the following as the main reason for the stress ratio becoming small.

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 uniform flexural rigidity, it being larger near the support than at the center. Also the slab is assumed as being supported linearly on the elastic beam, but actually 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 the 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 parallel system. 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 other incomputable factors.

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

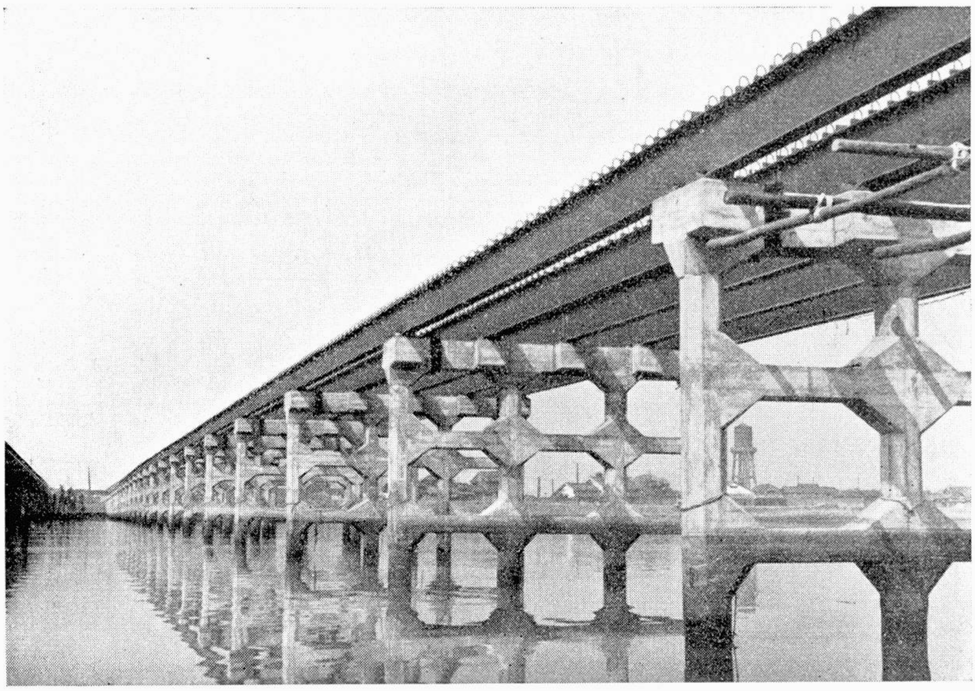

Photo. The Kanzaki Bridge under construction

Bibliography

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 and 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.

Summary

In order to know the difference between a single beam structure and a parallel beam structure, a static load test was done on the Kanzaki Bridge (composite beam bridge). The result of the measurement is shown by the ratio of the measured value to the calculated one. In obtaining the calculated value, several methods, i. e. the customary calculation method, the theory of the continuous slab supported by elastic beams, the theory of orthotropic plate, were used. From the measurement, the load distribution due to the slab was recognized in the bridge consisting of five main beams. The stress ratio and deflection ratio, in which this is taken into account, are 66% and 80% respectively. On the other hand, the experiment of a single beam structure shows that the above ratios are 89% and 84%, from which it is clear that the stress ratio is smaller in parallel beam structure. This is due to the cooperation of the slab and all the beams connected by the slab.

Résumé

Le pont Kanzaki a été soumis (pont à poutre composée) à une épreuve de charge statique afin de déterminer la différence de comportement entre les ouvrages à poutres simples et les ouvrages comportant des poutres à éléments parallèles. Les résultats obtenus sont mis en évidence par le rapport entre valeurs mesurées et valeurs calculées. Pour obtenir les valeurs calculées, on a employé plusieurs méthodes, à savoir la méthode habituelle de calcul, la théorie de la dalle continue supportée par des poutres élastiques et la théorie de la dalle orthotropique. D'après les mesures, on a constaté la répartition des charges dues à la dalle, dans le pont ici considéré et comportant cinq poutres principales. Le rapport des contraintes et le rapport des déformations, dans lesquels ce fait intervient, sont respectivement de 66% et de 80%. D'autre part, les résultats expérimentaux obtenus sur un ouvrage à poutres simples donnent pour les rapports ci-dessus des valeurs respectives de 89% et de 84%. Le rapport des contraintes est donc manifestement plus faible dans les ouvrages à poutres parallèles. Ceci résulte de la coopération entre la dalle et toutes les poutres auxquelles elle est associée.

Zusammenfassung

Die Kanzaki-Brücke (deren Tragkonstruktion aus einem Balkenrost besteht) wurde einer besonderen Belastungsprobe unterzogen, damit der Unterschied des Verhaltens zwischen Bauwerken, die aus einem einfachen Balken bestehen und solchen mit mehreren parallelen Balkenelementen bestimmt werden konnte. Die erhaltenen Meßresultate wurden mit den rechnerisch bestimmten Werten verglichen. Für die Bestimmung dieser theoretischen Werte kamen verschiedene Methoden zur Anwendung, so die übliche Berechnungsart, die Theorie der durchlaufenden Platte auf elastischen Stützen und die Theorie der orthotropen Platte. Aus den Messungen konnte man auf die Verteilung der von der Platte herrührenden Kräfte schließen. Das Verhältnis der errechneten zu den gemessenen Werten beträgt 66% für die Spannungen und 80% für die Durchbiegungen. Bei einem Bauwerk, das aus einem einzelnen einfachen Balken besteht, ergaben die entsprechenden Versuchswerte Verhältniszahlen von 89% und 84%. Die Messungen an einem System von mehreren parallelen Trägern ergaben also bezüglich der Spannungen wesentlich günstigere Werte. Diese Tatsache ist durch das Zusammenwirken der Platte mit den mit ihr verbundenen Trägern zu erklären.