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Field Testing of Existing Bridge on Remaining Load Capacity
Essais de charge et capacité restante d'un pont existant
Feldversuch zur Resttragfähigkeit einer bestehenden Brücke

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SUMMARY
This study is devoted to defining the load sharing of secondary members, such as lateral bracings, sway bracings and concrete walls compared with the loading test results of an existing steel bridge. Furthermore, it is examined how to evaluate the effects of secondary members of the structural load capacity of the existing steel bridge in the modelling for structural analysis.

RÉSUMÉ
Cette étude a pout but de définir la répartition de la charge du trafic sur les membres secondaires, tels que contreventements, entretoises et murs en béton, par comparaison avec les résultats des essais de charge d'un pont métallique existant. Elle montre également comment estimer les effets des membres secondaires sur la résistance du pont existant dans le cadre de l'analyse de la structure.

ZUSAMMENFASSUNG
Diese Studie ist der Ermittlung der Mitwirkung von sekundären Bauelementen wie seitlichen Verstrebungen, Querversteifungen und Betonwänden unter Verkehrsbelastung gewidmet. Dazu werden Vergleiche mit den Ergebnissen von Belastungsversuchen an einer bestehenden Stahlbrücke gezogen. Weiters wird untersucht, wie die Auswirkung sekundärer Bauelemente auf die strukturelle Belastungskapazität der bestehenden Brücke bei der analytischen Modellierung berücksichtigt werden kann.

1. INTRODUCTION

In recent years, some of the composite plate-girder bridges on urban highways in Japan have suffered fatigue damages which have occuered on the connections between main girders and secondary members such as lateral bracings and sway bracings[1]. Local corrosion have also occuered in the secondary members. Furthermore, cracks and vehicular collision have caused damages to the concrete wall parapets.

Lateral bracings and sway bracings are provided to ensure the lateral stability of bridges while their erection work is in progress or after the construction has been completed. Wall parapets are constructed to assure the safety for vehicular falls from bridge floor. These damages, therefore, do not reduce the reliability of steel bridges in direct relation to vehicular traffic loads.

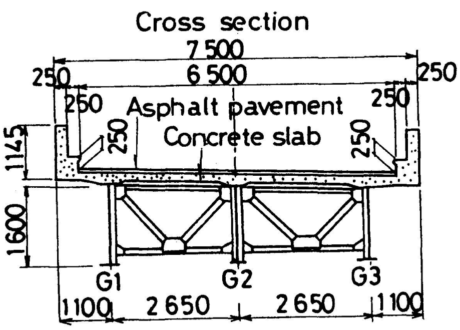
On the other hand, the secondary members form a three-dimensional structure with the main girders, and contribute to load distribution[2),3)]. They are considered effective for increasing the structural load carring capacity of the existing bridges. Failure to conduct periodical inspections and to perform adequate repair or reinforcement of these secondary members may help accelerate the damages, resulting in decreasing load carring capacity.

Through the field loading tests for an existing bridge, it was clarified that an individual secondary members can share the traffic load. Furthermore, it was examined how to evaluate the effects of secondary members on the structural load carring capacity of the exsisting bridge by modelling the structural analysis.

2. TESTED BRIDGE OVERVIEW

2.1 Structure

A steel bridge on the Hanshin expressway in the Umeda district in Osaka was chosen as a testing object. The bridge is 28.73m in effective span and 7.5m in total width. It is a simply-supported composite plate-girder bridge composed of three main girders, five pairs of intermediate sway bracings placed at the distance of approximatelly 4.8m, two pairs of end sway bracings each



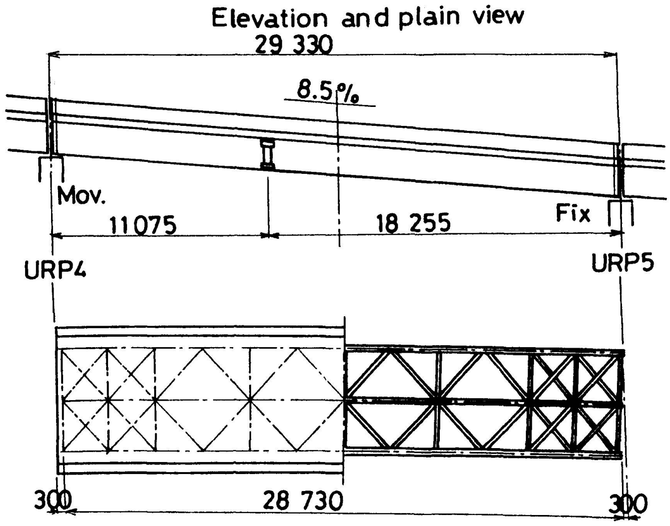


Fig. 1 General view of plate girder bridge

located at either girder end, and lateral bracings provided in a horizontal plane near the bottom flangein the exterior bays. The concrete deck slab is 170mm thick, which is overlaid with 75mm thick asphalt pavement. Concrete wall parapets of 250mm in thicknessand 1000mm in height are located alongside the edge of the concrete slab. Figure 1 illustrates the brige structure.

2.2 Historical background

This bridge has been served for vehicular traffic for approximately twenty-four years since its completion in 1965. The urban redevelopment of this district necessitated the traffic route to be altered, and this bridge to be demolished. Before this bridge was pulled down, loading tests and other various investigations were performed.

This bridge has not received many vehicular loads, because it was a ramp which provided vehicular access to the expressway. Since it was opened, the replacement of expansion joints was major maintenance work. Little deterioration has occurred in this bridge, and this bridge has been maintained in a sound condition.

3. TEST PROGRAM

3.1 Structural systems for loading tests

Figure 2 illustrates the structural systems for which loading tests were carried out. At first, loading test was performed to examine its load carrying capacity after 24 years of service. This is called the loading test of system 1. Next, loading tests evaluating the load share of secondary members such as lateral bracings, sway bracings and concrete wall parapets were carried out. Those tests are called the loading test of system 2, 3 and 4, respectively. In each system, lateral bracings, sway bracings and wall parapets were removed in a serial manner, and identical loading tests were excuted. By comparing the test results of each system, it is possible to clarify the extent of the load sharing at secondary members.

3.2 Loading

Loading trucks were used as a means of providing the required load. Figure 3 shows the dimensions of the

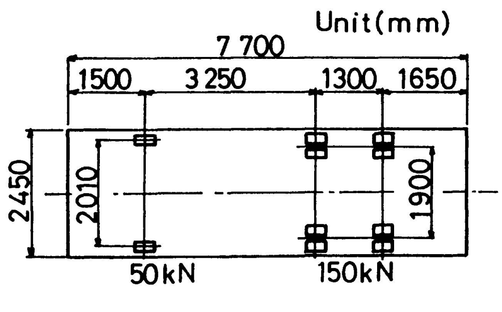


Fig.3 Loading truck

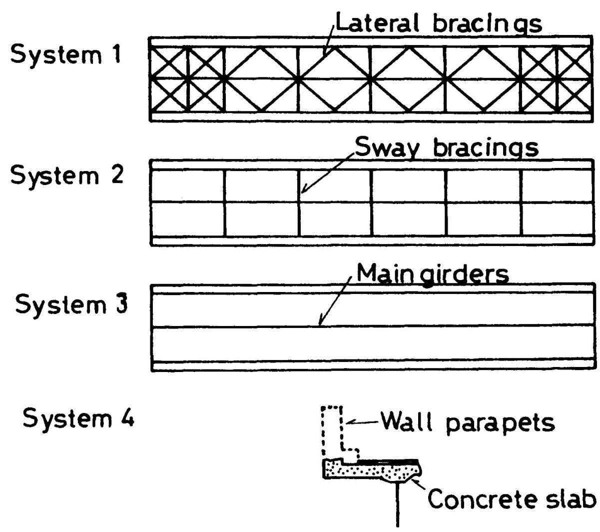


Fig.2 Structural systems for loading tests

loading truck. Figure 4 shows examples of loading truck positions. Tests are arranged so that loading is placed symmetrically on the travelling lane and in the passing lane, and also one lane only as an extreme case.

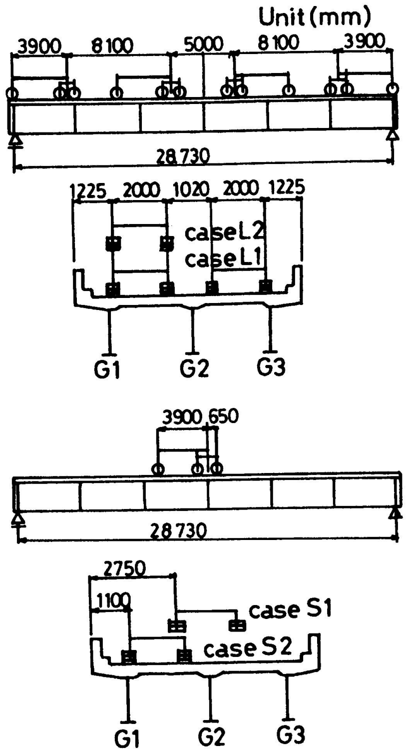


Fig. 4 Loading truck positions

3.3 Measurement items

Deflections and strains in main girders are measured with regard to the following items:

- Deflections of three main girders in the center of the effective span.
- Strains in the bridge-axis direction of the bridge at both top and bottom franges of main girders in the center of the effective span.

4. ANALYSIS OF THE TESTED BRIDGE

Analysis was conducted by using the four models. Table 1 shows the structural models used for the analysis. Table 2 shows the material properties of steel and concrete, used for the analysis. Models G1, G2 and G3 are used for the grid-girder analysis. Figure 5 illustrates the frame model used for grid-girder analysis. Model G1 is a structural model generally applied to the design of steel plate-girder bridges. In this model, the effective width of the slab complies with the provision in the Japan Specification for Highway Bridges[4).
Model G2 includes the assumptions employed in model G1 as well as adding the bending-rigidity of concrete wall parapets to the exterior girders. Model 3 includes G2's assumption, and in this model the torsional rigidity increased due to the installation of lateral bracings between the main girders is added to the rigidity of main girders. Model F is a model for the three-dimensional finite-element analysis. The mesh division of model F is shown in Fig. 6. For concrete deck slab, concrete wall parapets and webs of main girders, quadrilateral plate elements taking

Table 1 Structural models

Structural Model	Lateral Bracings	Wall parapets	Sway bracings
G1	N	N	C
G2	N	C	C
G3	C	C	C
G4	C	C	C

Note C:Considered
N:Not Considered

Table 2 Material properties

Material	Young's modulus	Poisson's ratio
Steel	2.06×10^{5}MPa	0.3
Concrete	2.94×10^{4}MPa	0.167

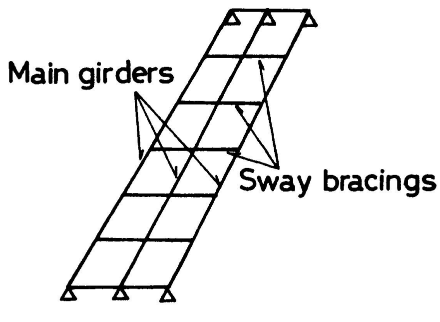


Fig. 5 Frame model for grid-girder analysis

with in-plane and out-of-plane rigidities are used. Top and bottom flanges of the main girders are divided into beam elements. The components of lateral baracings, sway bracings, are also divided into beam elements.

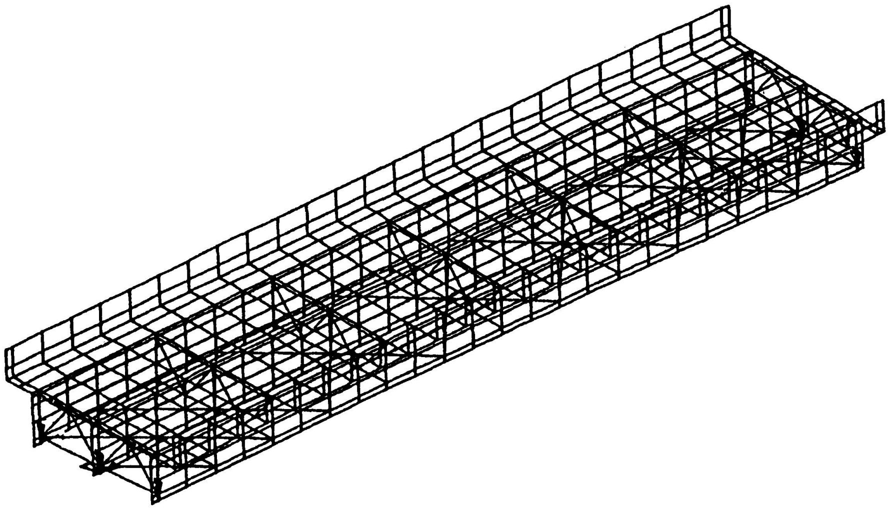


Fig. 6 Mesh division of Model F

5. RESULTS OF LOADING TEST

5.1 Load-carrying capacity in its existing condition

The measurement results of cross-sectional stress distributions in the main girders at the center of the effective span are shown in Fig. 7. The mesured values are smaller than the calculated values in design of this bridge. This indicates that the bridge which has served for twenty-four years completely meets the specified requirements. Differences between the measured values and calculated values are presumably resulted from the fact that effects of the secondary members on load sharing were disregarded in design.

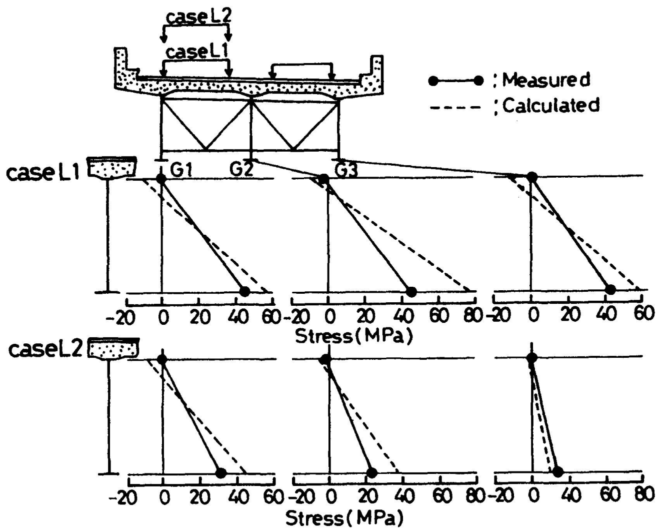


Fig. 7 Stress distributions in main girders

5.2 Effects of secondary members on load distribution

Figure 8 shows the results of the loading tests conducted for the each structural system.

Based on the test results of systems 1 and 2, the effects of lateral bracings on load distribution are described. In the symmetrical loading test (case S1) the measurement result of system 1 is almost similar to that of system 2. In the unsymmetrical loading test (case S2), the lateral distribution of system 1 differs from that of system 2. In the structural system 2 the deflection of the exterior girder(G1) increases. Stress in the bottom flange of girder G1 increases by about 10 percent.

The elimination of lateral bracings in system 2 affects the lateral distribution. This indicates that considering the effects of the lateral bracings on load sharing would be necessary to accurately evaluate load carrying capacity of existing bridges.

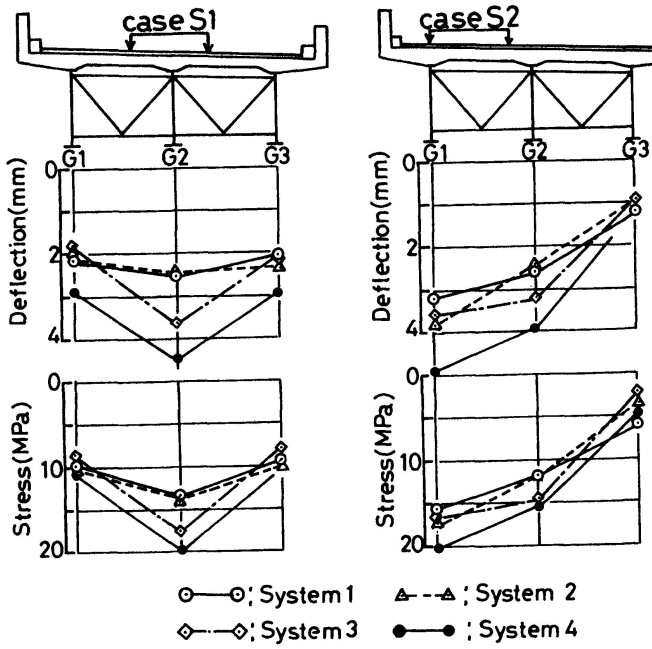


Fig. 8 Deflections and stresses in each system

For the comparison of the test results of system 2 with that of system 3, the effects of intermediate sway bracings on the load sharing are studied. In the results of system 3 in which intermediate sway barcings are eliminated, deflection of interior girder(G2) increases in both symmetrical and eccentric loading tests, and stresses in the bottom flange at the interior girder increase by about 30 percent in comparison with the result in system 2. Hence, the effects of intermediate sway bracings on lateral distoribution are significant. Based on the test result of system 4, the extent of the effect of concrete wall parapets on load sharing is studied. The rate of the increase in both deflection of main girders and stress in bottom flanges of the girders without concrete wall parapets are noticeable. This proves that the concrete wall parapets contribute greatly to the overrall stiffness of the bridge.

6. ANALYSIS RESULTS

Figure 9 shows the comparison between the calculated values and measured values of the deflections of the main girders in the structural system 1. Models G1, G2 and G3 represent the results of the grid-girder analysis, and model F represents results of the three-dimensional finite element analysis. Model G1 is generally used in the design of plate-girder bridges. With this model, the calculated values greatly differ from the measured values. The calculated values for the deflection are approximately two times as much as the measured values. The effects of concrete wall parapets are considered in model 2. In the symmetrical loading test(case L1), the calculated values derived from the analysis using model 2 are much closer to the measured values. In the unsymmetrical loading test (caseL2), the calculated values differ from the measured values.

In model G3, the torsional rigidity increased due to the installation of lateral bracings is considered. The calculated values at model G3 agree well with the measured values, proving that the use of model G3 would enable the accurate evaluation of the actual behavior of any existing girder bridge.
By using the model F, the better understanding of the structural behavior of the bridge could be achieved, but such an analysis requires a considerable set-up time and more expensible computational cost than model G3. Thus, the analysis with the use of model G3 is more appropriate and more economical method in the evaluation of the load carrying capacity of the existing bridges with the effects of secondary members.

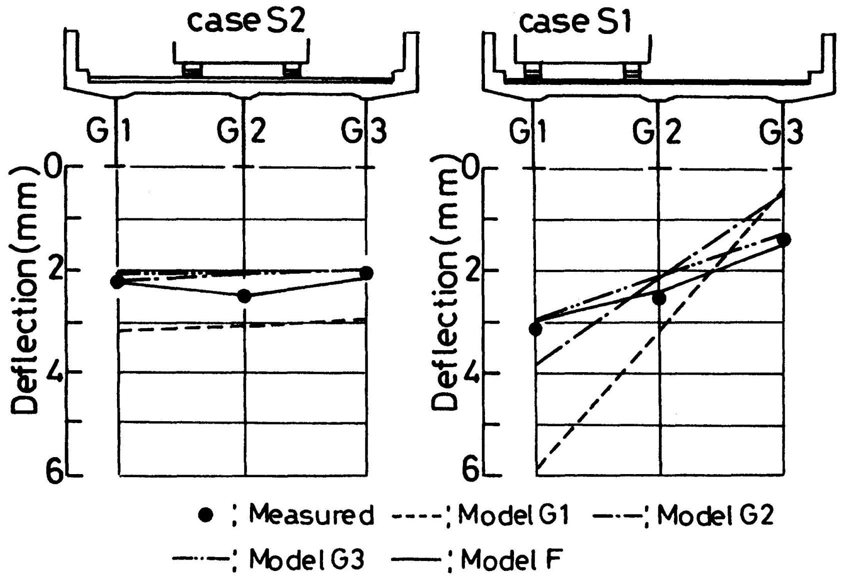


Fig. 9 Comparisons between measured values and calculated ones

7. CONCLUSIONS

From loading tests using an existing bridge, it can be seen that lateral bracings and intermediate sway bracings effectively act on the load distribution, reducing the stress generated in the main girders, and concrete wall parapets significantly contribute to the overrall stiffness of the bridge, reducing the stress generated in the main girders. Therefore, the analysis which also take of the effects of secondary members is required for the better understanding of the structural behavior of steel bridges. Both grid-girder analysis and three-dimensional finite element analysis may be available as methods to evaluate accurate load carrying capacity of existing bridges.

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