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Reduction of Plate Girder Depths for Bridges

Réduction de la hauteur de poutres métalliques de ponts

Verminderung der Trägerhöhe von Stahlbrücken

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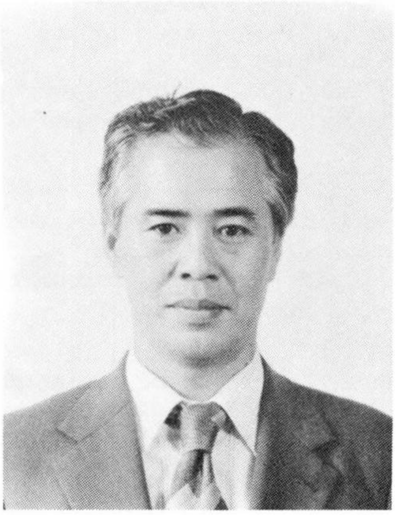


Hidehiko Abe, born 1931, graduated and obtained his doctoral degree, from the University of Tokyo, Japan. For 30 years he worked for the Japanese National Railways, mainly engaged in the design of steel bridges. Since 1984 he has been teaching structural engineering at University of Utsunomiya.

SUMMARY

The paper gives examples of remodelling work for reducing the depth of the plate girders of railway bridges on site, instead of replacement with new bridges, thus prolonging their lives. It describes the preliminary tests to select adequate procedures for construction, especially for field welding, and the method for calculation of the variation of stresses in various parts of the structure during the remodelling work.

RÉSUMÉ

Cet article contient des exemples de travaux de transformation de vieux ponts en acier, réduisant l'épaisseur des poutres en tôle, de manière à prolonger leur durée de vie, au lieu de les remplacer par de nouveaux ponts. On décrit les tests préliminaires qui permettent de sélectionner les procédures adéquates pour leur construction, notamment pour les opération de soudage sur chantier et pour la détermination des variations d'efforts dans les différentes parties de la structure durant les opérations de transformation.

ZUSAMMENFASSUNG

Dieser Beitrag beschreibt die Verlängerung der Lebensdauer alter Stahlbrücken durch Verringerung der Trägerhöhe und der Verstärkung. Er beschreibt auch die Vorversuche zur Bestimmung des geeigneten Vorgehens, speziell in bezug auf die Baustellenschweissungen und die Berechnung der Spannungen in den verschiedenen Bauelementen während der Instandstellungs- und Verstärkungsarbeiten.

1. INTRODUCTION

Many bridges are often replaced, not because of physical deterioration, but because of change of circumstances, such as improvement of the river, widening of the street underneath and necessity of reduction of the girder depth. The bridges, thus, have often unduly short lives.

The Japanese National Railways has many such experiences. There are, however, three cases where the depth of the girders of through type steel railway bridges, 14 spans in total, was reduced, instead of being replaced by new bridges. In two of them the bridges had originally been constructed in marshalling yard. But it was decided afterwards to lower the upper flanges of the outer girders of the bridges, because it was dangerous to the personnels working in the marshalling yards that the upper flanges were situated in a higher level than the rail level.

In the other case, the through girder bridge for Tokaido Shinkansen (the bullet train line between Tokyo and Osaka) adjacent to the platform of Kyoto Station was obstruction to extension of the platform, which was planned for increase of the capacity of the platform. These remodeling works were carefully planned, because in some cases all the work had to be done without interrupting or endangering the train operation.

The paper describes the sequence of work to be chosen for the maximum efficiency of the remodeling work, the calculated stresses in such an integrated girder, the procedure tests to select an adequate field welding method and so on.

2. OUTLINE OF REMODELING WORK

Takakura Viaduct was remodeled for extension of the present platform of Kyoto Station for Bullet Trains. Both Suikawa Bridge and Yamauchi Bridge were remodeled for safety and efficiency of personnels working in marshalling yards. The outline of the works is summerized in Table 1 and their cross-sectional configurations are shown in Fig. 1.

Table 1 Outline of Remodeling Works

Name of Bridge	Takakura	Suikawa	Yamauchi
Type of Structures	Through-type, Single track, Ballast floor, Welded	Through-type of 3-girders, 2-tracks, Open floor, Riveted	Through-type of 5-girders 4-tracks, Open floor, Riveted
Span length (m) and Number	35.0 x 1	16.2 x 1	22.6 x 10 13.2 x 2
Errection Method	Divided and lifted by a crane on the street underneath	New girder was errected on stagings	Divided and lifted by a crane on the bridge floor

3. STRESS CALCULATION

As the remodeling work proceeds, the stresses working in the cross-section of the existing girder and that of the added girder vary complicatedly. The example of stress calculation in Yamauchi Bridge (Span length is 22.6 m) at the center of span is described here.

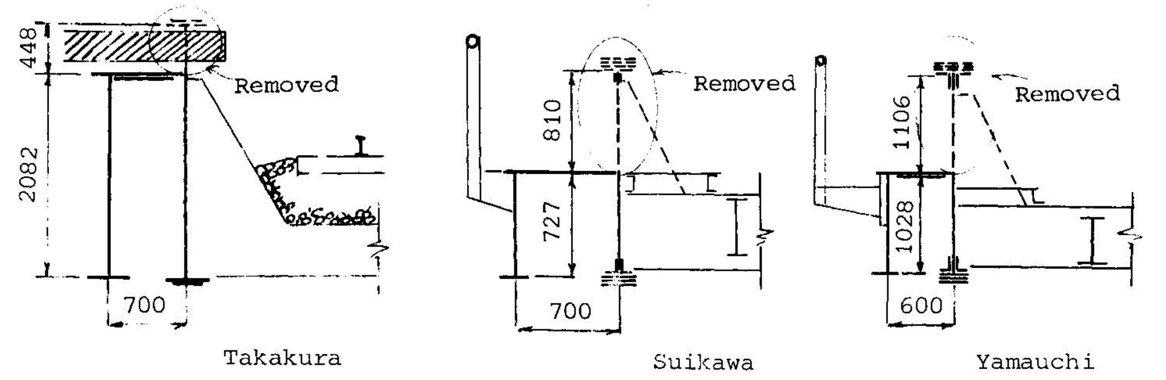


Fig. 1 Configurations of Cross-section of Bridges

The constructional steps chosen for the calculation are as follows;

1) First, the existing girder carries the dead load.
2) A new lower girder is connected to the existing girder, while the former is carrying its own weight only.
3) The portion of the existing girder above the upper flange of the added girder is removed.
4) The train load and the added dead loads such as the track and new side walk are carried by the integrated girder.

The calculated stresses change as shown in Fig. 2. The allowable stresses were reduced by 5 % and 10 % for compression and tension, respectively, for the existing girder, which was fabricated at a certain period between 1901 and 1950, as specified by the current related code.

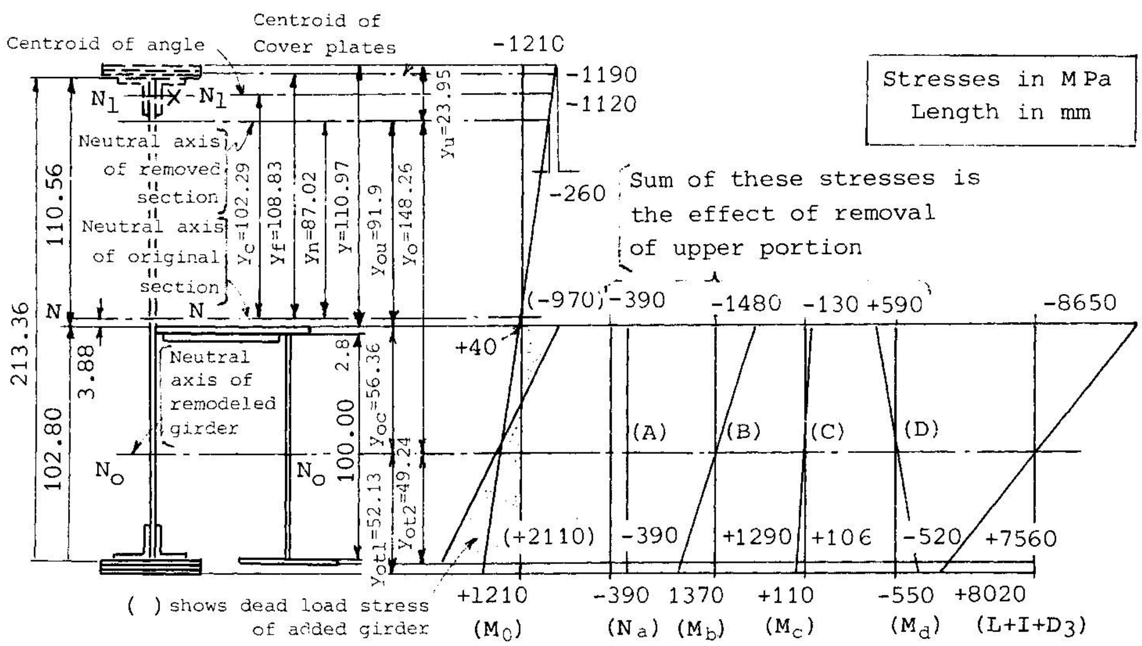


Fig. 2 Calculated Stress Variation at Span Center at Each Constructional Step

The portion of the dead load bending moment, which was carried by the upper portion to be removed from the existing girder, should be transferred to the integrated girder after removal. The stresses in the integrated girder can be calculated, breaking up the effect mentioned in Step 3) above, as follows;

a) The average compressive stresses which are induced in the integrated cross-section due to loss of the compressive stresses in the removed portion are to be evaluated.

b) The bending moment due to the resultant force of the stresses mentioned above with an arm length between the centroid of the removed cross-section and that of the integrated cross-section should be added.

c) The local bending moment which worked in the removed section only should be added.

d) The bending moment due to the weight of the removed portion should be deducted.

4. PRELIMINARY TEST FOR FIELD WELDING

Because this kind of construction was experienced for the first time, various preliminary procedure tests were conducted, in order to find proper conditions, such as edge preparation for welding, root gap, backing strip and welding sequence. In result solid flux backing of a special shape shown in Fig. 3, instead of backing strips of steel was chosen.

A possibility of considerable variation in the root gap for the welding between the flange edge of the added girder and the web of the existing girder was anticipated and a procedure to enable a sound welding with wide variation of root gap was finally developed.

As the result of many series of test, it was decided that the standard root gap should be 6 mm and a deviation of ± 2 mm should be tolerated without any modification and that if it happened to be smaller than 4 mm , the gap should be enlarged by an arc-air gouging before welding.

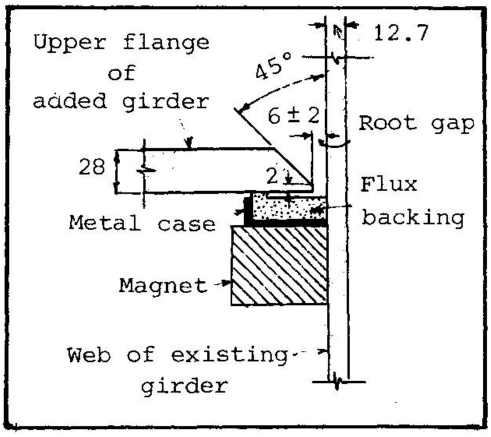


Fig. 3 Detail of Weld Preparation

Fig. 4 shows the cross-sectional shapes of test specimens with the first pass of weld deposited in groove of various root gap width. The root gap was varied from 2 mm to 8 mm . It was found that the weld with root gap of 6 mm was the best, with respect to penetration, back side of the first pass, uniformity of deposited bead. With root gap of 2 mm , a slight lack of penetration was recognized.

5. CONSTRUCTION

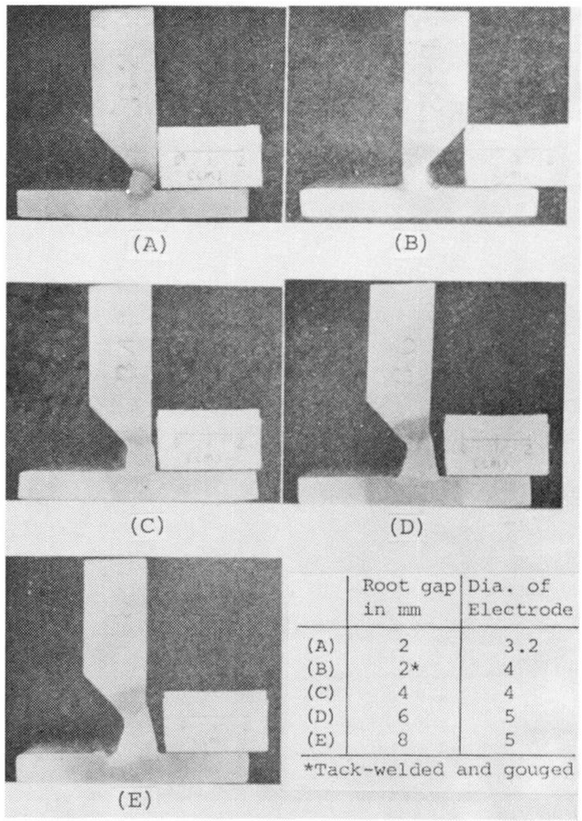
The existing girder was accurately measured and the girder to be added was so proportioned as to be well fitted to the existing girder which involved inaccuracy to some extent originally in fabrication. Prior to the field welding between the existing girder and the added girder, the diaphragms connected the both girders together first. In order to facilitate the adjustment of difference of deflections between them, the bolt holes on one side of the diaphragms were bored in slotted shape, while those on the other side were regular circular holes, as shown in Fig. 5. The deflection at each step during the construction was checked.

The surface of the web plate of 80 mm in breadth along the weld line was sufficiently cleaned, prior to welding. The part to be welded and its neighbourhood were preheated in 50c° to 100 C°. Care was taken to dry sufficiently the electrodes and the flux backings to be used in a controlled hearth.

In a rainy or windy weather and in humidity beyond 80%, the welding work was suspended. The sequence of welding was selected as shown in Fig. 6, in order to minmize the shrinkage deformation due to welding.

The back-side welding was unnecessary as a rule. But if any defect was detected by inspection from the back side, it was removed and rewelded.

The web of the existing girder was cut by a flame-cutting machine, which was automatically moved, guided on rails placed on the flange of the added girder, and the cut edge was ground smoothly.



	Root gap in mm	Dia. of Electrode
(A)	2	3.2
(B)	2*	4
(C)	4	4
(D)	6	5
(E)	8	5

*Tack-welded and gouged

Fig. 4 Preliminary Test to determine an adequate root gap length

6. CONCLUDING REMARKS

Japanese National Railways success fully lowered the depth of main plate girders of no less than fourteen spans of through-type bridges. The remodelled bridges have been in use without any trouble for more than ten years since then, and their lives have, thus, been prolonged.

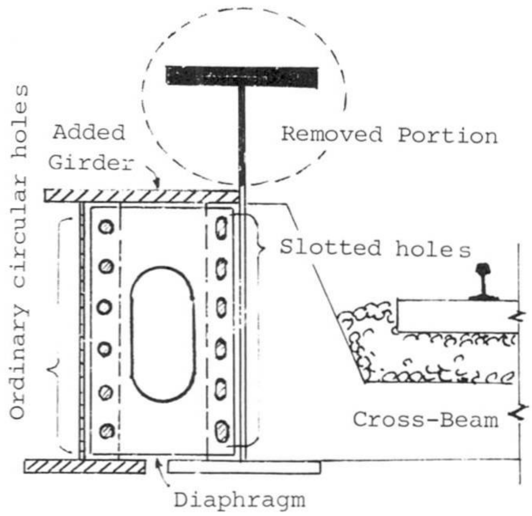


Fig. 5 Bolt Holes in Diaphragm

In these examples, the girders to be added carried their own weight only, when they were connected with the existing girders. But there may be cases where it is more efficient to use steel material of considerably high strength for the added girder and a proper portion of the dead weight of the existing girder is carried by the added girder, to make the best use of their respective allowable stresses. It will, however, require such a device as shown in Fig. 7, for adjustment of the ratio of carried load between the existing girder and that to be added.

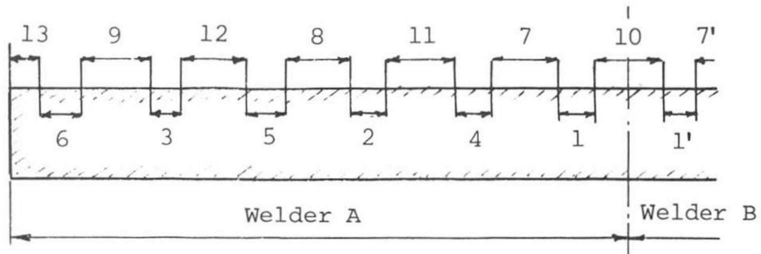
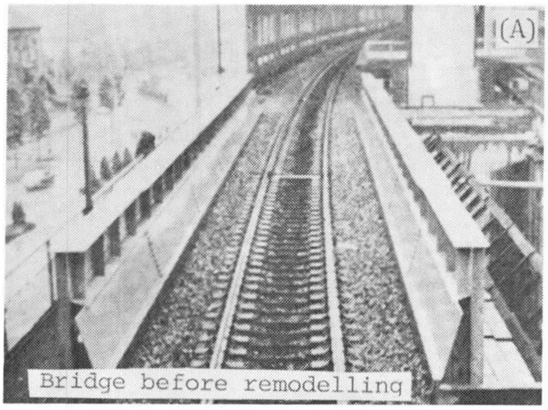


Fig. 6 Sequence of first pass in welding


(A)
Bridge before remodelling

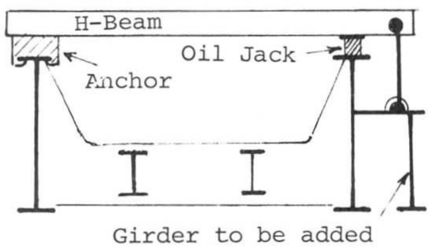
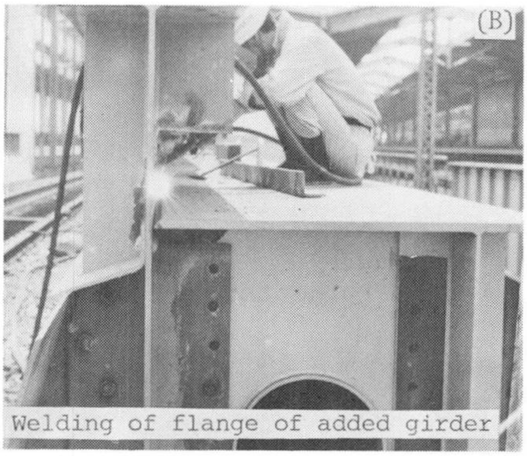
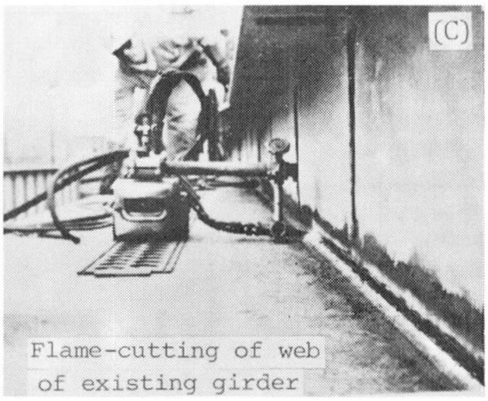
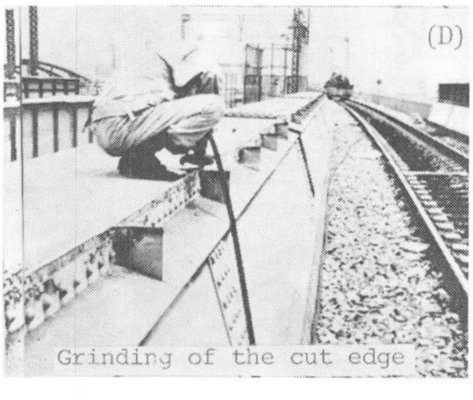
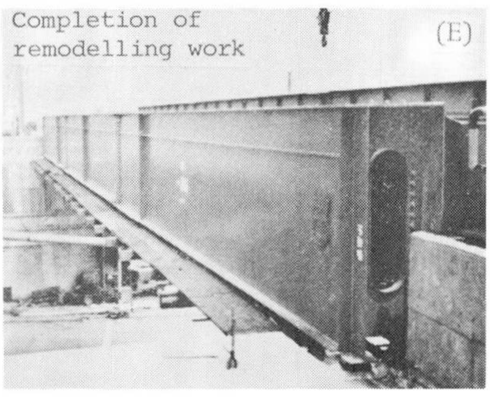


Fig. 7 Device for adjustment of carrying load


(B)
Welding of flange of added girder


(C)
Flame-cutting of web of existing girder


(D)
Grinding of the cut edge


Completion of remodelling work
(E)

Photos 1 to 5 Remodeling work of Takakura Bridge, Kyoto