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Application of Composite Girders to Highway Bridges under Consideration of Maintenance

Application de poutres mixtes aux ponts d'autoroutes du point de vue de l'entretien

Anwendung von Verbundträgern auf Autobahnbrücken, von der Instandhaltung her betrachtet

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1. Introduction

In Japan, simply-supported plate girders have generally been used for urban express-highway bridges. Recently, damage at reinforced-concrete slabs and expansion joints of bridges has caused a serious problem. Several years after completion of bridges, repair works of bridge decks including expansion joints have often been forced to be carried out on some bridges, so that serious traffic congestion has been caused.

There will be many reasons for the cause of such damage: from working loads, the reasons are

- 1) Increasing of the intensity of working loads,
- 2) Increasing of the traffic vehicles;

from structural rigidity, the reasons are

- 1) A reinforced-concrete slab is generally lacking in flexural rigidity,
- 2) Main girders supporting a floor system may be subjected to unequal deflections,
- 3) Overall flexural rigidity of some bridges may not be sufficient to prevent the slab damage.

To solve these problems in the structural rigidity, the following new construction methods as shown in Fig. 1 and 2 have been proposed:

- 1) Closed steel-grating floor,
- 2) Floor beam with concrete filled in steel form,
- 3) A method to connect two simply-supported girder by a reinforced concrete cross beam, to reduce the otherwise required number of expansion joints.

Even if one of these methods is used individually, a remarkable effect on rigidity could be expected. Furthermore, the rigidity can be increased much more by combining these methods all together. These new construction methods have the following advantages:

- 1) The load-carrying capacity in bending of a closed steel-grating floor is larger than that of an ordinary reinforced-concrete floor,

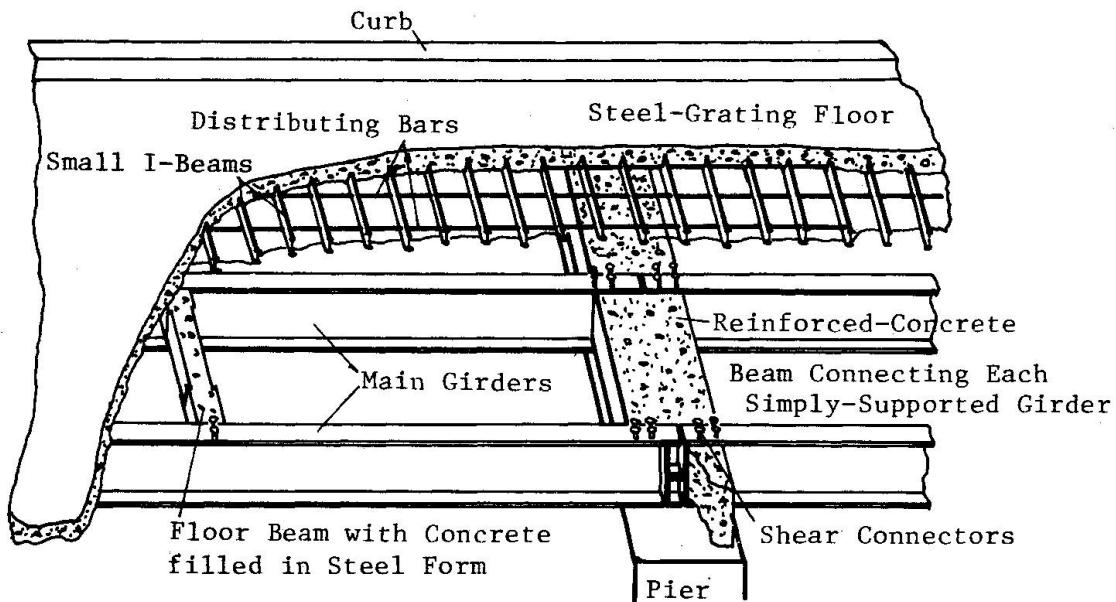


Fig. 1 Schematic View of Composite Girder

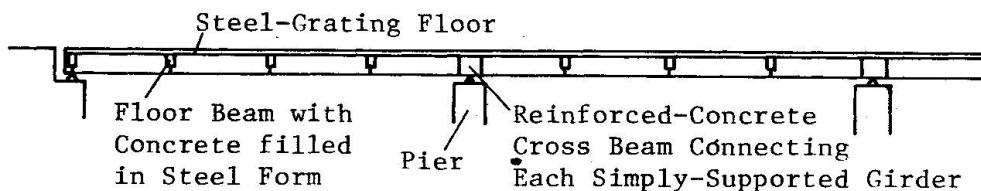


Fig. 2 Side View of Composite Girder

- 2) Its structural elements are of simple construction,
- 3) Easy and fast fabrication and erection works can be expected,
- 4) The flexural rigidity of this type of bridge is larger than that of a conventional bridge,
- 5) The number of expansion joints which will be one of the cause of damage could be reduced.

Compared with the conventional method, these new construction method will give greater durability to bridges. Therefore, bridge service life can be extended and the maintenance cost of bridge can be reduced.

In this paper, the three new construction methods and their application to actual highway bridges will be discussed.

2. Closed steel-grating floor

The authors have already published several reports for the study on a closed steel-grating floor. 1],2] Gaining credit for its great usefulness, it has been applied to the floor of a great number of highway bridges in Japan. 3]

It consists of a concrete-filled steel grid frame of small parallel I-Beams connected by suitable steel bars, to which thin plate is welded so as to act a mould as shown in Fig. 3. It is also called the I.B GRATE floor.

This type of floor has the following advantages:

- 1) The dead load can be reduced because of the smaller thickness of the floor,
- 2) Accuracy for this fabrication is higher than an ordinary reinforced-concrete slab because it is fabricated in a shop,
- 3) Since assembling and removing of moulds and placing of reinforcements in the field are not required, construction time required for erection of a bridge can be shortened,
- 4) The load-carrying capacity is larger than that of a reinforced-concrete slab against the same bending moment.

It is quite possible to reduce the damage at a floor and the maintenance cost of a bridge by using the I.B GRATE floor.

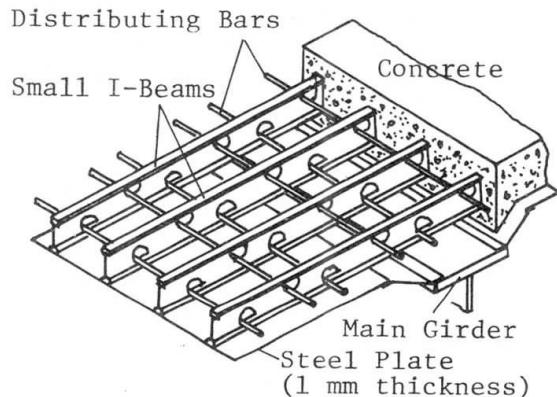


Fig. 3 Details of Grating Floor System

3. Floor beam with concrete filled in steel forms

When floor beams for ordinary plate girder bridges are to be manufactured, many accurate and yet complicated operations are required, for example, full-size marking and moulding, making holes, fastening bolts, and so on. To decrease these complex operations, an idea about a new type floor beam which could provide easy and fast fabrication and erection, has been developed by the authors.

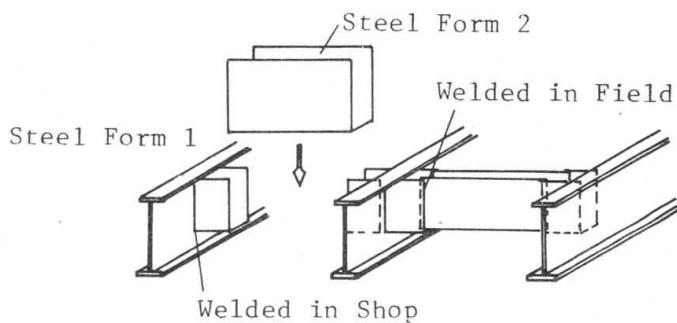


Fig. 4 Erection of Steel Forms

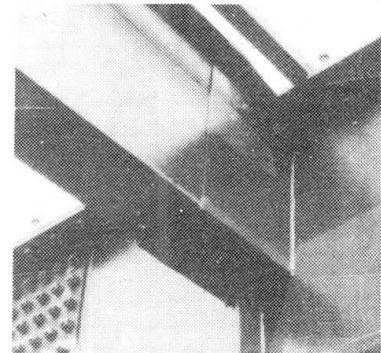


Fig. 5 Connection

As shown in Figs. 4 and 5, a U-shape Steel Form 1 is welded to a main girder in a shop. Then, a U-shape Steel Form 2 is attached to the Steel Form 1, and is welded at each joint in the field. After placing steel bars in the Steel Form 1 and 2, they are filled with concrete simultaneously with slab concrete casting. By these processes a concrete floor beam is produced and acts as one member together with slab.

At the connections to the main girder, steel bars are arranged through the web plate of the inner main girder to resist a bending moment, and some shear connectors are welded on the web plate of the outer main girder to resist a shearing force as shown in Fig. 6. Accordingly, the floor beam is kept in continuity at the connections to the main girder. Furthermore, connections of the slab to

the floor beam are strengthened by distributing some stirrups in the Steel Forms and anchoring them in the slab.

This type of floor beam has the following advantages:

- 1) Because the floor beam can act together with the slab, the rigidity of the floor beam will be increased, hence the distribution of loads will be improved and the rigidity of bridge itself will be increased.
- 2) The slab is stiffened by the floor beam, which especially will contribute toward stiffening the slab effectively at the end of girder.
- 3) In the floor beam filled with concrete, bolts and rivets are not used at all, so it is unnecessary to make hole and to assemble temporarily girders and floor beams in a shop. Consequently, it is expected that fabrication will become very easy.
- 4) It is also so easy to erect the bridge in the field that experienced workers are not required.

From the point of designing this floor beam, it will be pointed out that,

- 1) The steel forms (thickness in 3.2 mm or 4.5 mm) for a floor beam may be regarded as a stress member until the concrete is hardened, and may not be regarded as the stress member for working loads after the concrete has been hardened.
- 2) The floor beam filled with concrete works together with the concrete slab, so the both are designed as a reinforced-concrete T-beam.

Grid-frame rigidity at a composite girder bridge using this floor beam is 3 or 4 times as much as that of the ordinary composite girder bridge. Hence, the overall rigidity of the bridge become greater, and unequal deflections of the main girders supporting the floor become remarkably so small that their bad effect on the slab is considerably decreased. Therefore, the durability of the bridge may be increased by using this floor beam. Also, the structural elements of this bridge are so simple that its maintenance will be very easy.

4. A method to connect two simply-supported girders by a reinforced-concrete cross beam

It is advisable to use this new method for multi-span bridges such as viaducts, flyovers, etc. On a pier which will carry an intermediate support after connection, two simply-supported girders erected individually are connected by a reinforced-concrete cross beam cast simultaneously with slab concrete. These two connected girders have the same function as a continuous girder for live load and dead load after composition with the slab concrete.

As shown in Fig. 7, first of all, moulds are set about 70 cm away from each end of the girders and steel bars are placed in the moulds between each main girders. Furthermore, suitable steel bars are placed in the slab along the main girders to reinforce the slab for a negative bending moment as shown in Fig. 8. Then, concrete

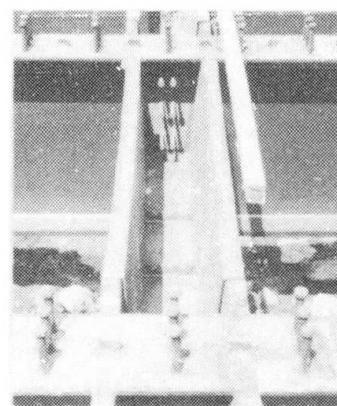


Fig. 6 Steel Form

is placed in the moulds simultaneously with casting of the slab concrete.

Now, the authors designed several details near the end of main girders as shown in Fig. 9, and compared each other in static strength by tests, which showed that they were practically equal in the strength except Type (a) which was weakest. Among them Type (d) has been recommended by the authors.

Assumptions of design for girders are as follows:

- 1) The connected main girders function in the same way as two simply-supported girders until the concrete at the connection is hardened.
- 2) The connected main girders are regarded as two simple girders for dead and live loads in its design. However, they are regarded as a continuous girder for the calculation of deflection.
- 3) The connecte section at the connection is proportioned for sectional forces due to the loads applied to a continuous girder.

This method has the following advantages:

- 1) It is a simple matter to design and fabricate the main girder as two simple girders, and its standerdization could be done easily.
- 2) The erection of simple girders requires only light operations.
- 3) If two simply-supported girders are connected by a reinforced-concrete cross beam, it is unnecessary to build expansion joints, resulting in smooth traffic running.
- 4) Main girders are designed as a simple girder, and are connected by a reinforced- concrete cross beam, and become continuous girders. Therefore, the main girders show the same behavior as a continuous girder. So, in fact, the main girders are subjected to less stresses compared with a designed value

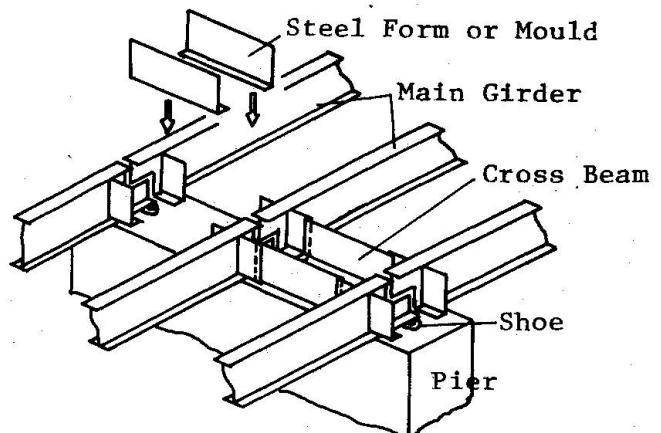


Fig. 7 Details of Connection

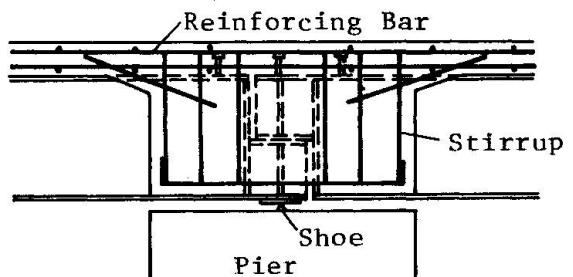


Fig. 8 Placement of Bars

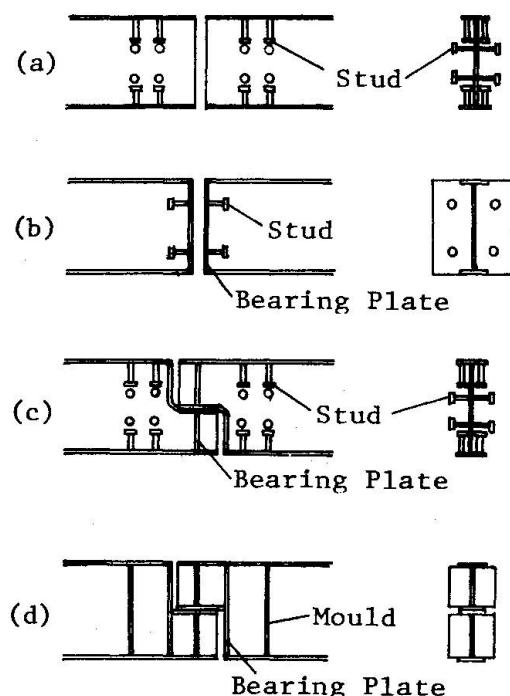


Fig. 9 Details near the Ends of Main Girders

in the region of positive bending moment.

5) The deflection could be reduced by connecting simple girders together to make a continuous girder, then the slab gets less bad effect. Reducing the number of expansion joints could solve the problem on slab damage.

This construction method is a remarkably better one compared with that of conventional bridges not only for reducing the number of expansion joints which used to cause damage, but also for greatly reducing their maintenance cost.

Now, it should be noted that this method can be applied to a bridge whose span length is less than 30 m from the authors' experience, because it seems that a longer bridge will require further studies on detail at the connection. In addition, girder sections may be uniform throughout the whole length with a section at the span center which is proportioned as a simple girder.

5. Application examples

a) Example 1

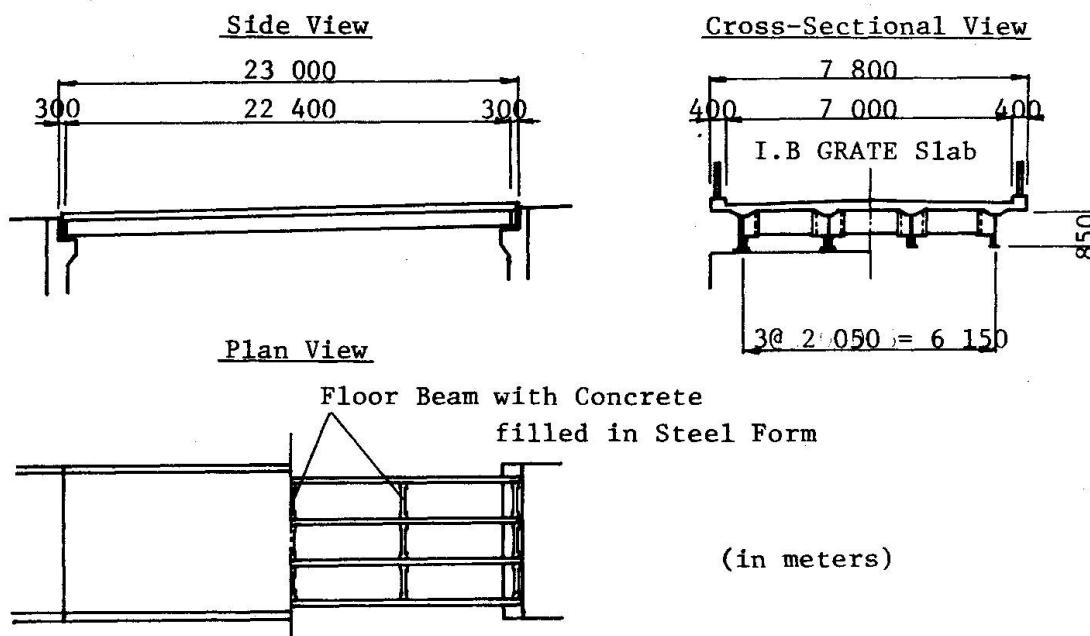


Fig. 10 General View of Bridge

An actual example of application to a simple girder bridge is introduced, which was constructed in Japan in 1974 with the I.B GRATE floor and the floor beam filled with concrete. 4]

As shown in Fig. 10, main items of the bridge were bridge length of 23 m, total width of 7.8 m, span of 22.4 m, and a design live load for the bridge was 20 tons truck load specified at the Specifications for Highway Bridges in 1972, Japan Road Association.

In fabricating this bridge, full-size marking and moulding were not done except those of the main girders, because a large number of connections to connect a floor beam with a main girder, were easily adjusted by using the floor beam filled with concrete when the bridge was built in the field. It took about 9 days to construct the super-structures of this bridge, and the erection

works were faster and easier than those of an ordinary bridge with a similar length (Figs. 11 and 12).

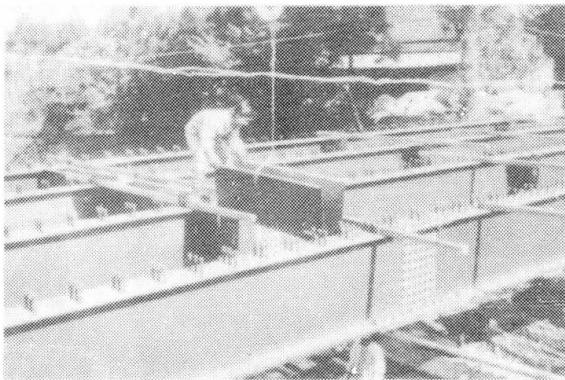


Fig. 11 Erection of U-shape Steel Form



Fig. 12 Setting of I.B GRATE Floor

b) Example 2

An example of application to the ceiling of box-culvert through which an express highway runs, is illustrated as seen in Fig. 13, which was constructed in Japan in 1975.

In recent years, Japan has suffered from public nuisances due to construction works at the community around construction sites. It will be the only solution for solving this serious problem to shorten the length of construction time. In such circumstances, the new methods which have been described in the preceding paragraph are quite suitable, because these new methods can cut construction time by 1/3 or 1/2 compared with using conventional methods.

In the case of construction of a box-culvert, it has proved advantageous to apply the proposed new methods, because they certainly cut the construction time, meet a requirement to secure an open space under its ceiling as a road, and yet they do not cause any trouble against continuation of the main construction works. Furthermore, to avoid traffic congestion caused by maintenance works, especially for repainting, galvanized main girders can be used together with a thin zinc iron plate for a bottom plate of the I.B GRATE floor, because much less repainting work is required.

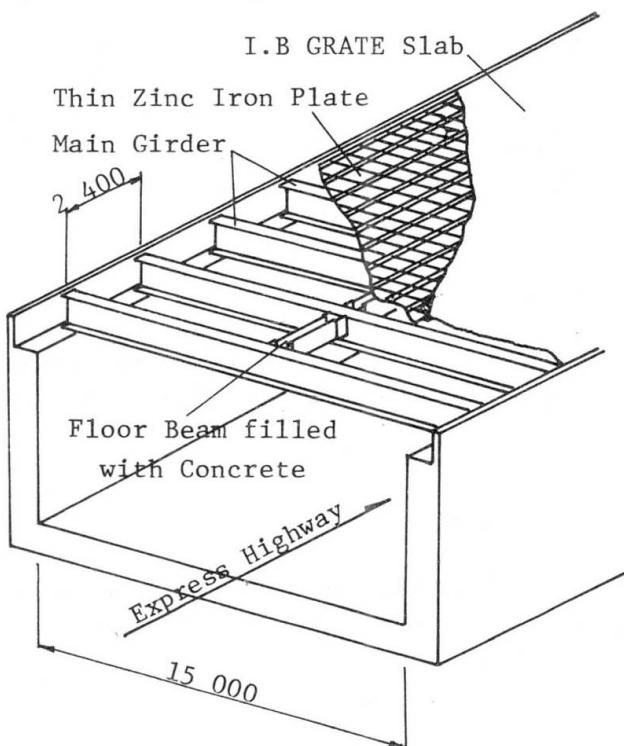


Fig. 13 Schematic View of Box-Culvert

6. Conclusions

A structure should have more durability with less maintenance so that it can perform its function fully and safely in its life. To meet such requirement, new three construction methods for bridge were proposed with discussion in this paper in order to give greater durability to individual structural parts, resulting in providing the bridges with greater overall durability.

These new methods have flexibility enough to be applied to other bridges.

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SUMMARY

Three new construction methods which are to be applied to composite plate girder bridges, are proposed with discussion in order to increase durability of bridges.

RESUME

On présente trois nouvelles méthodes de construction de poutres mixtes et leur influence sur la durée de vie des ponts.

ZUSAMMENFASSUNG

Es werden drei neuartige Baumethoden für Brücken mit Verbundträgern vorgeschlagen und im Hinblick auf Erhöhung der Lebensdauer der Brücke diskutiert.