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Steel Bridge Decks Realized with Corrugated Plates and Plane Sheets Connected by High Strength Bolts

Tabliers de pont métallique réalisés au moyen de tôles pliées et planes reliées par des boulons à haute résistance

Stählerne Fahrbahntafeln aus mit hochfesten Schrauben verbundenen kaltgeformten und ebenen Blechen

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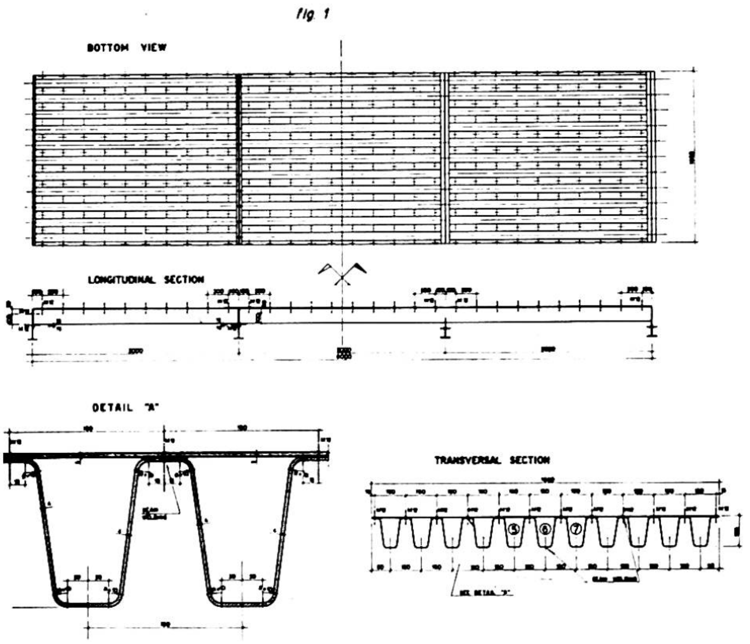
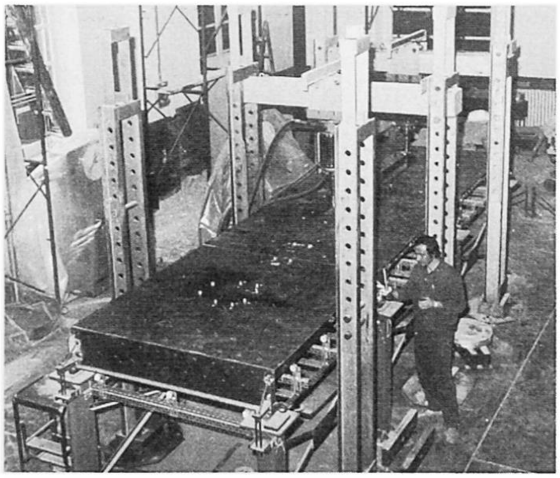
Introduction

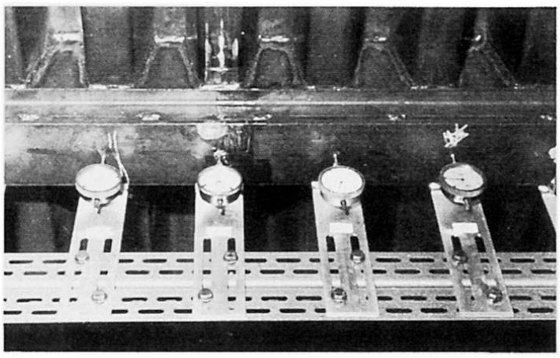
The results of an experimental research on a model of steel orthotropic bridge deck are here briefly summarized.

Tests were performed in the University of Rome in collaboration with the Italsider society during the years 1973-75.

The model, scale 1:2, was made by an upper plane sheet connected by high strength bolts to a botton folded sheet, the resulting deck being similar to an orthotropic plate with closed ribs (fig. 1 2 and 3).







In such a type of deck weldings are almost completely eliminated, with reduction of costs expecially when highyield strength steels are employed.

This type of deck could be adopted also in civil or industrial buildings where heavy liwe loads must be carried with limitation on permanent loads.

Tests in the elastic range

Static tests in the elastic range have been performed by loading the plate in a number of points with two types of load. One acting on a small area simulated the action of a truck wheel; load acting on a large area represented the action of coupled wheels.

By making use of mechanical devices, the absolute displacements of the plate and tre relative displacement between bolts and sheet have been meastured. Strains have been measured by means of electrical strain gages.

From the several tests performed the following conclusions can be drawn:

a) the connection of flat sheet and corrugated sheet by means of high strength bolts is reliable due to the fact thet relative displacements have not been noticed and the behaviour exhibited by the model has been nearly linear.

b) the torsional rigidity of this deck type is small and similar to the one of orthotropic plates with open ribs. Fig. 4 compares the values of stresses meaured at midspan of ribs and the corresponding theoretical values furnished by the Pelikan-Esslinger method for several values of the relative stiffness. A good agreement is achieved for values of x as little as 0.2. This effect is seemingly due to the shape loss of the bottom corrugated sheet.

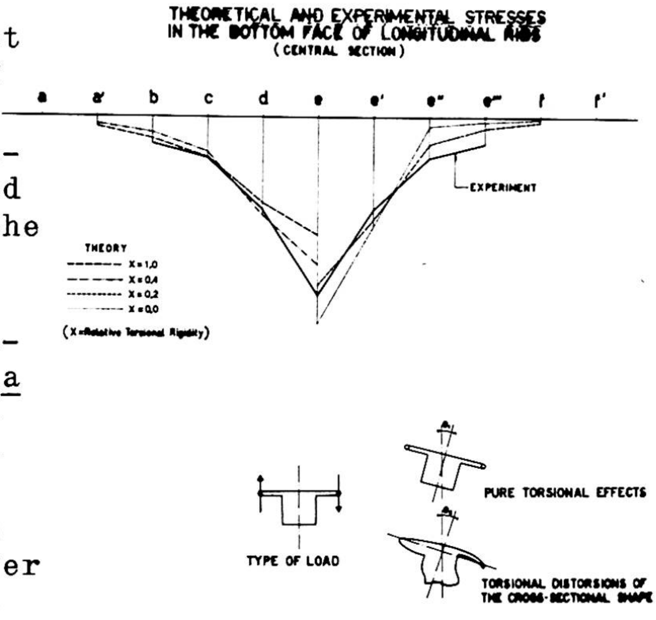


fig. 4

c) local stresses within the loaded area are rather high due to the fact that the deflection length of the top flat sheet is of the order of the bolts distance (fig.5).

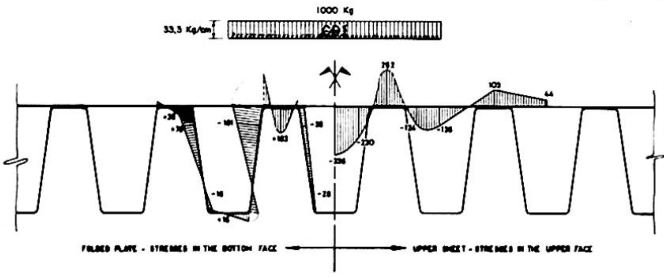


fig. 5

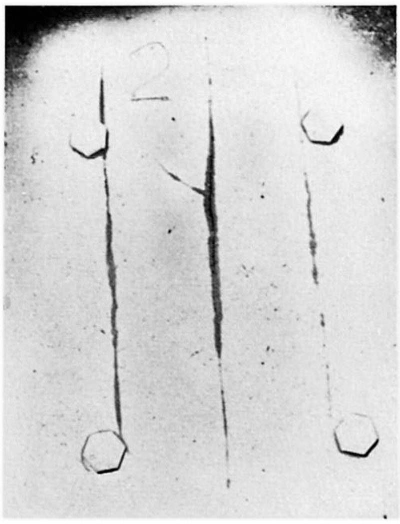
With regard to points b) and c) a better behaviour of the model could be obtained with a double row bolts, possibly in a "quinconces" setting.

Fatigue tests

Tests under pulsating loads have been performed to get information on the predominant types of fractures and on the importance of fatigue in comparison with the static behaviour.

The minimum value of the pulsating load was about 1/20 of the maximum and therefore it can be assumed, for all practical purposes, as equal to zero.

The load has been applied at seven different spots and it has been increased after a suitable number of cycles.



Displacement have been recorded by means of trasducers. Penetrating liquid of the Spotcheck type has been employed in order to spot fractures.

The result of tests are here summarized:

a) local fractures occur in the top flat plate within the loaded area and are of the type shown in fig. 6.

b) stresses which cause fracture are nearly the same as those associated with fatigue fractu re in a flat sheet under pure bending, i.e. no reduction in strength has been noticed because of the presence of bolts.

Collapse test

A section of the model has been tested under proportional loa- ding up to collapse after the fatigue fractures have been repaired.

The load has been increased stepwise, each step being 1/10 of the theoretical collapse load. At each level a numer of loading cy- cles has been performed until a steady situation has been reached (differences between deformations of two subsequent cycles smaller than 5/100 mm).

In the central loaded area stress coat paint has been used to spot yielded regions.

The test confirmed that the model presents a very high load- carrying capacity, collapse load being about ten times the service load. This is due to a progressive load transfer from the loaded area to the adjacent areas caused by the membrane behaviour of the top flat sheet. This effect can be clearly seen in fig. 7 where plots of loads vs displacements are shown, as well as in fig. 8 which shows stresscoat paint fracture on the top sheet near the load.

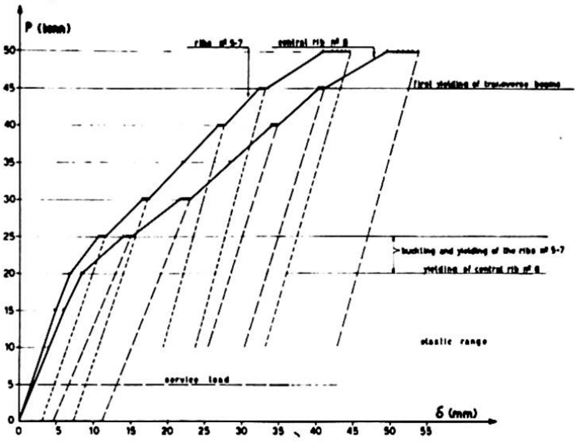
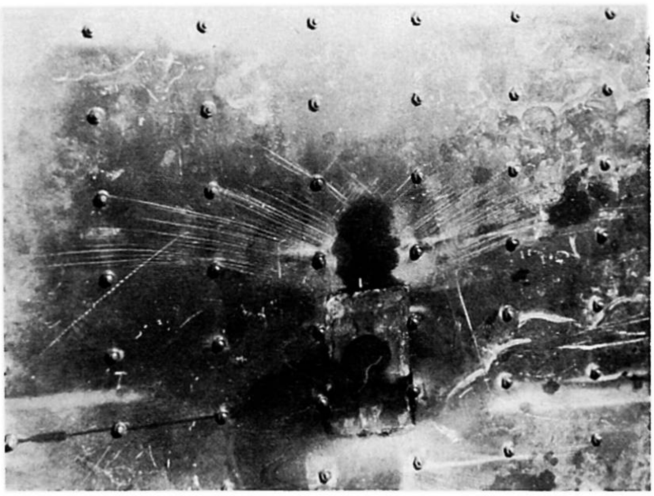


fig. 7



The continuation of the research with forces acting in the pla- ne of the plate is in future scheduled. These forces will probably emphasize local instability with subsequent reduction of the load- carrying capacity of the model.

References

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SUMMARY

The results of an experimental research on a model of steel bridge deck are briefly summarized. The model was made by an upper plane sheet connected by high strength bolts to a bottom folded sheet to form a deck similar to an orthotropic plate with closed ribs. Static tests in the elastic range as well as tests under pulsating loads and under proportional loading up to collapse have been performed.

RESUME

On présente les résultats d'une recherche expérimentale sur un modèle de tablier de pont métallique. Le modèle était constitué par une tôle supérieure plane reliée au moyen de boulons à haute résistance à une tôle pliée inférieure de façon à former un tablier du type plaque orthotrope avec nervures fermées. On a effectué des essais statiques dans le domaine élastique, des essais sous charges variables et enfin des essais de chargement proportionnel jusqu'à la rupture.

ZUSAMMENFASSUNG

Die Ergebnisse von Versuchen an einem Modell einer stählernen Leichtfahrbahntafel werden kurz erörtet. Das Modell wurde mit einem oberen ebenen Blech hergestellt, das durch hochfeste Schrauben mit einem unteren kaltgeformten Blech verbunden war, so dass eine Art orthotroper Platte mit Hohllängsrippen entstand. Die Versuche wurden statisch im elastischen Bereich, auf Ermüdung mit Ursprungsbelastung sowie bei Proportionalbelastung bis zur Traglast durchgeführt.

Welding of High-Strength Steels

Soudage des aciers à haute résistance

Schweissen von hochfesten Stählen

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1. INTRODUCTION

It should be taken great pains with not only the characteristics of materials but also the welding methods from a viewpoint of risk of failure of long-span bridge made of high-strength steels. In the preliminary report, the outline of way to build-up of long-span truss bridge, i.e., design, materials, fabrication and erection were discussed. In this report, the conditions and methods of welding and the quality control of welding during the fabrication course may be presented.

2. CONDITIONS OF WELDING

As a procedure test to determine welding conditions of high-strength steels 70 kg/mm^2 and 80 kg/mm^2 classes, the following tests were conducted prior to fabrication;

(1) lamellar tear test,
(2) restrained cracking test,
(3) tests on the performance of corner weld joints,
(4) tests to check residual stresses due to welding, and
(5) tests to investigate the various characteristics of the actual members using full scale models.

The maximum heat input of less than 50 KJoule/cm during welding was preset based on the results of such tests to avoid "bond" embrittlement of weld joint. Welding conditions including minimum preheat temperature, maximum preheat temperature, interpass temperature, and preheat temperature for tack welds were determined from the condition mentioned above. (Table 1)

The three factors of kind of materials, restraining and hydrogen are said to be main ones causing weld cracking. The first was settled by employing the steels passing the new specification. The second was thought not to be serious problem because of no steel plate having great restraining with neighbour plate in the Osaka Port Bridge. Therefore, the final factor was remained as the most considerable one which brought so called transverse cracking, i.e., the cracking along weld line. The suitable control method with which hydrogen entry could be minimized as much as possible was settled for fabrication in order to avoid such possible cracking.

Table 1 Preheat Temperature

Minimum Preheat Temparature (°C)

High-Strength Steels of 70 kg/mm^2 and 80 kg/mm^2 Classes				
Welding Method / Kind of Joint / Thickness (mm)	Covered Arc Welding	M I G * Welding	Submerged Arc Welding	
	Butt , Fillet , Corner		Butt	Fillet
t $\leqq$ 50	100	80	100	80
t > 50	120	100	150	100

* M I G Welding..........Inert Gas Shielded Metal Arc Welding.

Maximum Preheat Temparature and Interpass Temparature

Thickness (mm)	Temparature
t $\leqq$ 50	200°C and under
t > 50	230°C and under

3. WELDING METHOD

The automatic welding technique was made every effort to use in order to uniformalize the fabrication conditions. Among the automatic methods, two techniques of submerged arc welding and MIG welding were selected. The latter has an advantage to avoid the possible occurrence of cracking because of small heat input, but involves the serious problems of ill efficiency of work and of increased hardness in weld joint. Therefore, the first was used as the butt and fillet welding and the latter as the corner one. Also the following three types of preheating methods were used;

(1) electric preheating type with automatic control, (Photo 1)
(2) fixed burner type, and
(3) manual burner type.

The separate preheating method was specified for each type of weld joints. In welding major members, symmetrical preheating and symmetrical welding methods were employed to secure higher fabrication accuracy and minimize residual stresses. (Photo 2)

The preheating prior tack welding of small heat input and rapid cooling was carried out with careful concern, and its temperature was set higher by 20-40°C than that of primary weld.

4. QUALITY CONTROL OF WELDING

The close quality control system is necessary for the use of high-strength steels 70 kg/mm^2 and 80 kg/mm^2 classes to long span bridge. Although the detail explanation of such system is omitted in this report, the non-destructive inspections involves serious and many problems. Especially at the ultrasonic examination of corner joint shown in Fig.1, as the ultrasonic flaw detector possessed by the fabricators were different in the kind and the material and dimension of probe, the inspection was quite different each other, and the correlation between flaw and echo from discontinuity captured on the Braun tube could not be obtained. Therefore, the inspection standard was rechecked from the measurements with various test material.

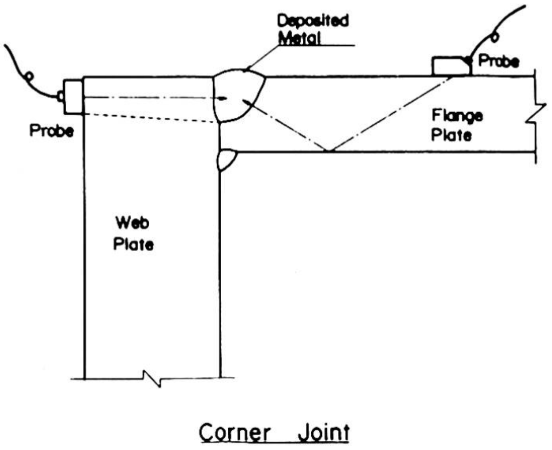

Fig. 1 Corner Joint

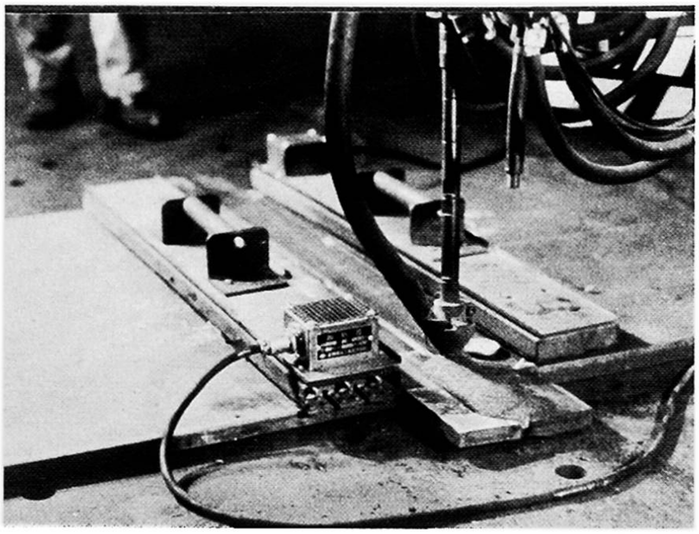

Photo 1

This photograph shows preheat performance with electric preheating equipments.

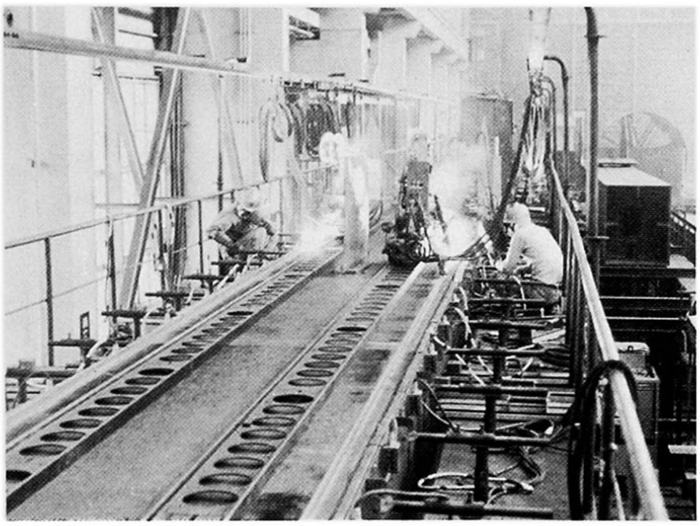

Photo 2

This photograph shows the appearance of symmetrical welding.

SUMMARY

Due attention was paid to the problem of cracking and embrittlement of weld joints of high-strength steels. The maximum heat input of less than 50 K Joule/cm during welding was preset and the preheat temperature was determined. The suitable control method with which hydrogen entry could be minimized was settled for fabrication. Among the automatic welding methods, two techniques of submerged arc welding and MIG welding were selected.

RESUME

On a prêté une attention particulière au problème des fissures et des ruptures fragiles dans les joints soudés en acier à haute résistance. L'apport de chaleur durant le soudage a été limité à 50 K Joule/cm et la température de préchauffage, déterminée. On a fixé la méthode de contrôle permettant de réduire au minimum la teneur en hydrogène. Parmi les méthodes de soudage automatiques, on a retenu le soudage sous flux et le procédé MIG.

ZUSAMMENFASSUNG

Der Vermeidung von Rissen und Sprödbrüchen in Schweissnähten an hochfesten Stählen wurde besondere Beachtung geschenkt. Das Wärmeeinbringen während der Schweissung wurde auf 50 K Joule/cm begrenzt und die Vorwärmetemperatur bestimmt. Man verwendete eine geeignete Kontrollmethode, um die Wasserstoffaufnahme möglichst niedrig zu halten. Unter den automatischen Schweissmethoden wurden das Unterpulverschweissen und das MIG-Verfahren ausgewählt.