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Artikel: Temperature stresses observed in welded constructions in Belgium

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Temperature stresses observed in welded constructions in Belgium.

Bei Schweißarbeiten in Belgien festgestellte thermische Beanspruchungen.

Contraintes thermiques constatées lors des travaux soudés en Belgique.

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This note will be limited to a consideration of thermal stresses, regarding which it may be observed that although we do not know their exact magnitude we do know, only too well, that it is considerable. As a single example in support of this fact mention may be made of a Vierendeel girder wherein no special precautions had been taken, as they should have been, to relieve the thermal effects of the thick weld seams of 36 mm side: when the last site weld was being formed the end of the bridge was observed to be lifted off its bearing, and a fold appeared in the lower boom. In this instance the weight of the longitudinal member in question was approximately 80 tons.

Elastic action appears in the following forms:

1) Shortening of the members.
2) Deformations.
3) Internal stresses, which may or may not be attended by cracking and breakage.

1) *Shortening of members.*

Members are shortened as a result of shrinkage from welding, but by making the members slightly longer than necessary it is possible to ensure that the final dimensions are sufficiently accurate.

2) *Deformations.*

Deformations are more especially apt to be considerable at places where the weld seams are asymmetrical. Any given deformation is proportional to the free length of the member in question, where the latter is able to deform in the direction of the seam, and it is inversely proportional to the thickness of the member. Most of the welded bridges in Belgium are Vierendeel girders with a parabolic upper boom, and since this boom is in compression there is every advantage in making it as stiff as possible. There are two methods of doing so:

a) The use of double T girder having its flanges in the form of standard rolled joists 400 to 500 mm deep, or broad flanged beams (Fig. 1). Technically, from the point of view of welding, the second of these methods is open to the objection that the weld is formed on the web of the joist which is of limited thickness, so that the deformation is considerable. Moreover, most of the methods commonly used in the workshop for straightening bent pieces when cold are dangerous: for instance, in certain shops where joists used for booms of girders had been straightened cold, a series of cracks were found running at right angles to the weld in the web, due to a partial cold working effect on the metal (Fig. 3).

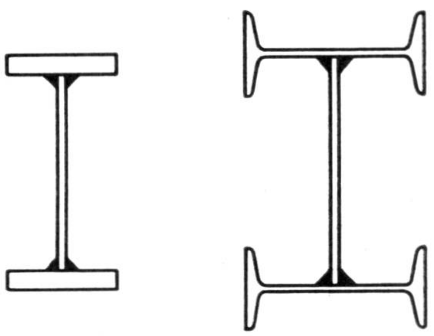

Fig. 1.
Types of booms for Vierendeel bridges.

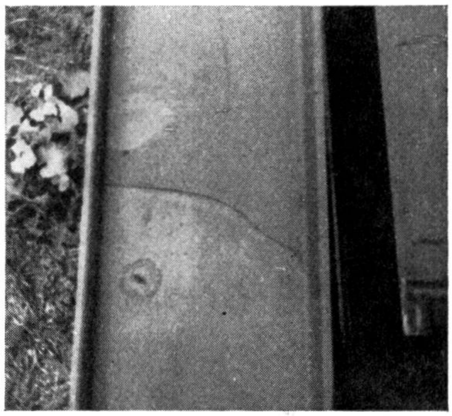

Fig. 2.
Fractured beam of an upper boom of a Vierendeel bridge.

The amount of these deformations can and should be reduced by suitable choice of

a) The thickness of the pieces to be joined, and

b) The sizes of electrodes to be used.

For this and other reasons, electrodes of large diameter should be avoided, especially for the first layers. In most cases deformations can practically be eliminated if a symmetrical arrangement of the beads is adopted.

In Vierendeel girders and rigid frames, such as are becoming general in Belgium, use is being made of connecting gussets having a section built up from a web with a flange (Fig. 3). Such gussets may be formed from four flanges b), with symmetrical beads, or with two flanges a). The arrangement shown at b) is evidently to be preferred, but it calls for a large number of welds. In box-shaped members (Fig. 4), notwithstanding the symmetry of the welds, a twisting effect has been observed, due partly to the amount of metal deposited in the different beads not being precisely equal and partly to the fact that the elements themselves are not precisely similar.

3) *Internal stresses.*

The shrinkage of welds gives rise to stresses extending over a considerable zone, and these may be dangerous especially where there already are pre-existing stresses. For instance, in rolled sections of great thickness the deposition of a weld bead may have the effect of causing fracture, and in Belgium breakages have often been found in Grey beams which, as is well known, are subject to

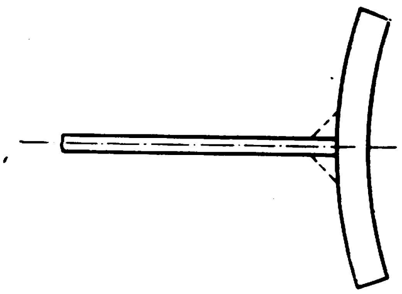

Fig. 3.
Inverted camber given to a welded plate.

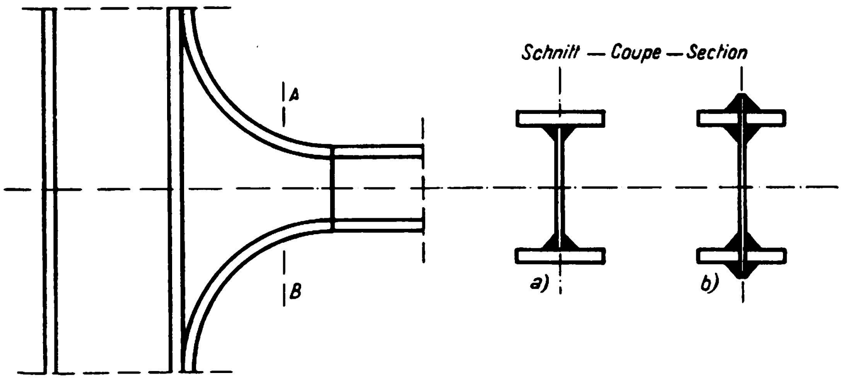

Fig. 4.
Details of panet point with tangential jointing.

heavy rolling stresses. The drilling of a hole may render a rolled piece unsuitable for welding because of the interruption of the cold worked zone, giving rise to cracks and breakage in the sound part of the piece. The crowding of many weld

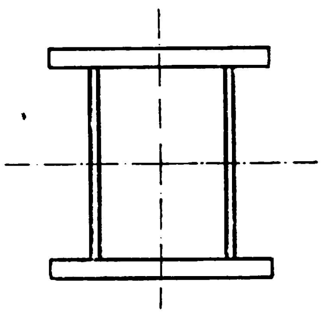

Fig. 5.
Welded box girder.

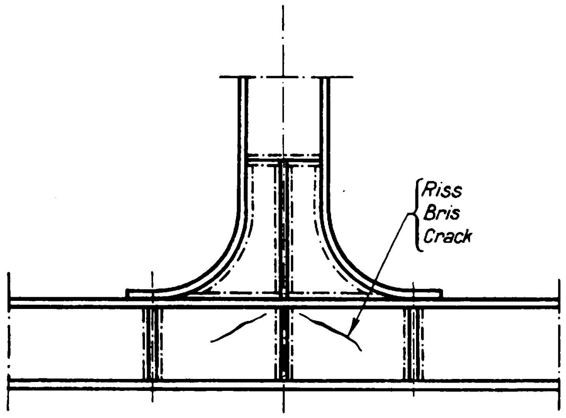

Fig. 6.
Details of panet point with characteristic cracks.

beads into a small space should be avoided, and in the same way it is desirable to avoid placing welds of widely different dimensions close together.

In Belgium there have been cases of accidents arising in the welding of the bracings to the intersections in Vierendeel girders with a number of stiffeners (Fig. 7), and also in the welding of the cruciform-sectioned verticals of these bridges (Fig. 8). In plate web girders the stiffeners are a source of great trouble, and if it were possible to diminish their number by suitably increasing the thickness of the web the design of such bridges would be improved. Another evident improvement in the design of stiffeners would be to continue them as far as the tensile boom (Fig. 9).

The chief danger attending the presence of these thermal forces is that any resulting cracks or breakages may not appear in the workshop immediately after the welding operation. Microscopic cracks may then be imperceptible, and escape detection until some months later: a form of delayed action which is peculiar to welding and which has never been completely explained. The effect may perhaps be similar to that sometimes observed in accidents to cast pieces where, likewise, the breakages have occurred at unexpected places.

An instance occurred in which the presence of a large number of cracks in the parent metal and weld metal was disclosed in the course of alterations to a girder of double T-section when a welded plate was being cut out with the blowpipe (Fig. 10); these cracks were probably due to will scale on the plate.

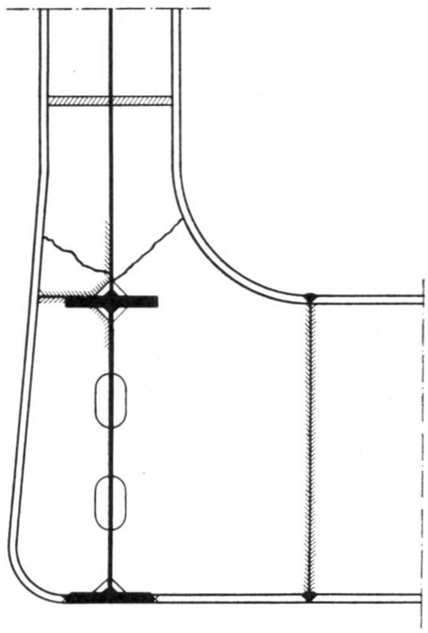

Fig. 7.
Characteristic cracks in uprights of Vierendeel bridges.

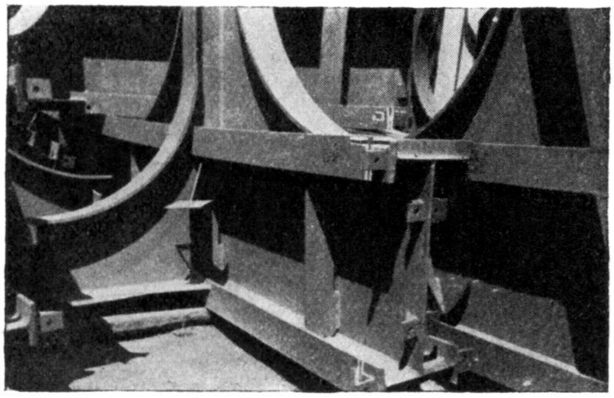

Fig. 8.
Connection of cross girder and standard.

Another example worthy of mention is the following: some months after the welding of a bridge had been completed and the concrete decking had been laid down a sudden breakage occurred along the axis of the welded joint of the web, accompanied by a noise (Fig. 11). In the author's opinion the shrinkage stress in the seams of the flanges, which were 36 mm thick, had been sufficient to initiate cracking in the bead along the web.

Precautions to be taken to reduce the effects of thermal stresses.

Advance precautions.

A) *Positions and dimensions of welds.*

Welds should be so placed as to receive a minimum of stress under all conditions, and their close proximity to one another should be avoided. The proper detailing of connections is a matter of the first importance to which, in Belgium, a great deal of consideration has been given and this has led to the perfecting of a curved form of joint with tangential connections, which is suitable for use both in bridges and in building frames. Mons. *Campus* has described this form of joint before the present Congress.

B) *Dimensions of the members to be joined.*

The thickness and length of the members must be carefully proportioned, and for the following reasons the thickness of plates should not be below a certain minimum:

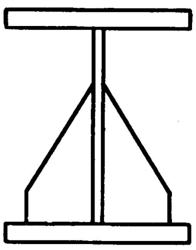

Fig. 9.
Stiffener to a single web beam.

1) It has been found that in thin sheets at temperatures of 600 to 800^0 C the elongation is considerably reduced, with a consequent increased tendency to cracking.
2) Excessive penetration of the welding is to be apprehended, and this, from an operating point of view, fixes a minimum thickness.
3) To minimise warping.
4) To reduce the number of stiffeners.

C) *Sequence of welding.*

The sequence in which the various beads are deposited should not be left to the decision of the welder, but should be laid down in a programme with a view to minimising the shrinkage of the welds, just as is done for the shrinkage of concrete work.

D) *Metallographic analysis of the parent metal and weld metal.*

This is a matter of the first importance, for it is necessary to be quite certain as to the weldability of the parent metal.

E) *Fabrication of members.*

This must be done with special care so as to avoid excessive tolerances which might call for an excessive amount of weld metal, with harmful effects.

F) *Special precautions.*

In special cases a particular procedure, such as pre-heating before welding, may need to be laid down.

Working arrangements.

G) *Electrical apparatus.*

Since it is important to be able to ensure a uniform deposition of weld metal great attention should be paid to the electrical installations and these should be specially designed for welding work. The transformers and cable leads must be such that drop in voltage and amperage is limited to a reasonable amount. A sufficient number of electric measuring instruments should be provided and continuously observed.

H) *Choice of electrical characteristics.*

This choice is a matter of great complexity. The temperature of deposition should be kept down in order to reduce thermal strains, but at the same time this temperature must be high enough to ensure good penetration. For any given jobthat is to say for steels of known composition when using electrodes of suitable type, where the pieces to be joined are of given thicknesses — there are certain optimum electrical characteristics which should be adopted.

I) *Limit of maximum diameter for the electrodes to be used.*

In Belgium a large proportion of the accidents which have occurred have been attributable mainly to the desire of the workshops to lessen their labour costs by working with too large a diameter of electrode. It is essential that this diameter should be kept down, in the first place on account of the danger which attends too rapid cooling and secondly because of the danger of using too heavy a current and causing correspondingly high thermal stresses. The maximum diameter of electrode has been provisionally fixed by the Ponts et Chaussées Belges at 5 mm, except for the bottom layer where the limit is 4 mm.

J) *Precautions to be taken in winter work.*

In Belgium it is now forbidden to carry out welding at temperatures below 4° C.

K) As a means of deciding the best method to adopt it would obviously be an advantage if the order of magnitude of the thermal stresses could be related to the various methods of procedure available, and in Belgium a group of engineers has entrusted a government laboratory with the task of making a complete survey of this subject.

Procedure after Operations.

L) The handling of pieces while still hot from welding should be forbidden.

M) Arrangements should be made to ensure that welds are allowed to cool slowly.

N) It is to be hoped that the experiments now embarked upon in Belgium will lead to the development of special devices which will be both practical and economical for lessening thermal stresses after welding.