Shrinkage of welded trussed structures

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Objekttyp: **Article**

Zeitschrift: **IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht**

Band (Jahr): **2 (1936)**

PDF erstellt am: **18.05.2024**

Persistenter Link: https://doi.org/10.5169/seals-3174

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Shrinkage of Welded Trussed Structures.

Schrumpfungen in geschweißten Fachwerken.

Retraits dans les poutres réticulées soudées.

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The shrinkage causes changes in the workpiece due to the resistance of the metal parts against the tendency of the hot zones to retract when getting cold. This phenomenon causes changes of length as well as waving and rotation in the different elements of the structure.

The shrinkage and the internal stresses caused require special care in the case of welded trusses, as the capacity of bearing of such structures, especially for repeated loads, is dangerously reduced by the internal stresses.

A short time ago we made a large number of shrinkage measurements on a test steel truss. The truss was afterwards statically and dynamically tested in detail in the Federal Institute for the Testing of Materials, Zürich.

The aim of these measurements was to get definite knowledge of the different kinds of shrinkage and their values, as they happen in actual welded structures.

The test girder measured 6 m in length and 1,5 m in height and was dimensioned for a load of 50 tons applied in the middle of the span.

The bottom chord was composed of two angles 80×12 mm, the top chord of two angles 100×12 mm and a plate 100×12 mm. All the diagonals were built of two T-sections No. 14.

The joints of one half of the girder were carried out with 12 mm butt V-weld with welded roots, those of the other side were designed with fillet side and front welds of different thicknesses and lengths.

The end joints of the one diagonal were composed of side fillet welds 8 mm thick and 27 cm long, those of the other side of 11 mm resp. 19 cm.

In the top chord there were two 12 mm V-welds, running along a length of chord of 3,60 m.

The connections of the diagonals as well as of the gussets to the top chord and in the middle of the bottom chord were made of two V-welds of 60 cm length and 12 mm thickness.

The thicknesses of the welds mentioned above were necessary to enable satisfactory transmission of the forces. They are relatively big compared with the small dimensions of the girder. Large amounts of shrinkage were therefore expected from the beginning, so every precaution to avoid their development was observed, but it was of course not possible to prevent them totally.

In spite of this, mantelled electrodes were used as from the metallurgic point of view they are to be preferred, although they increase the shinkage. High current was applied in order to increase the rate of melting. For the welding, electrodes of 4 mm diameter of the Swiss make "Arcos Stabilend", joined to

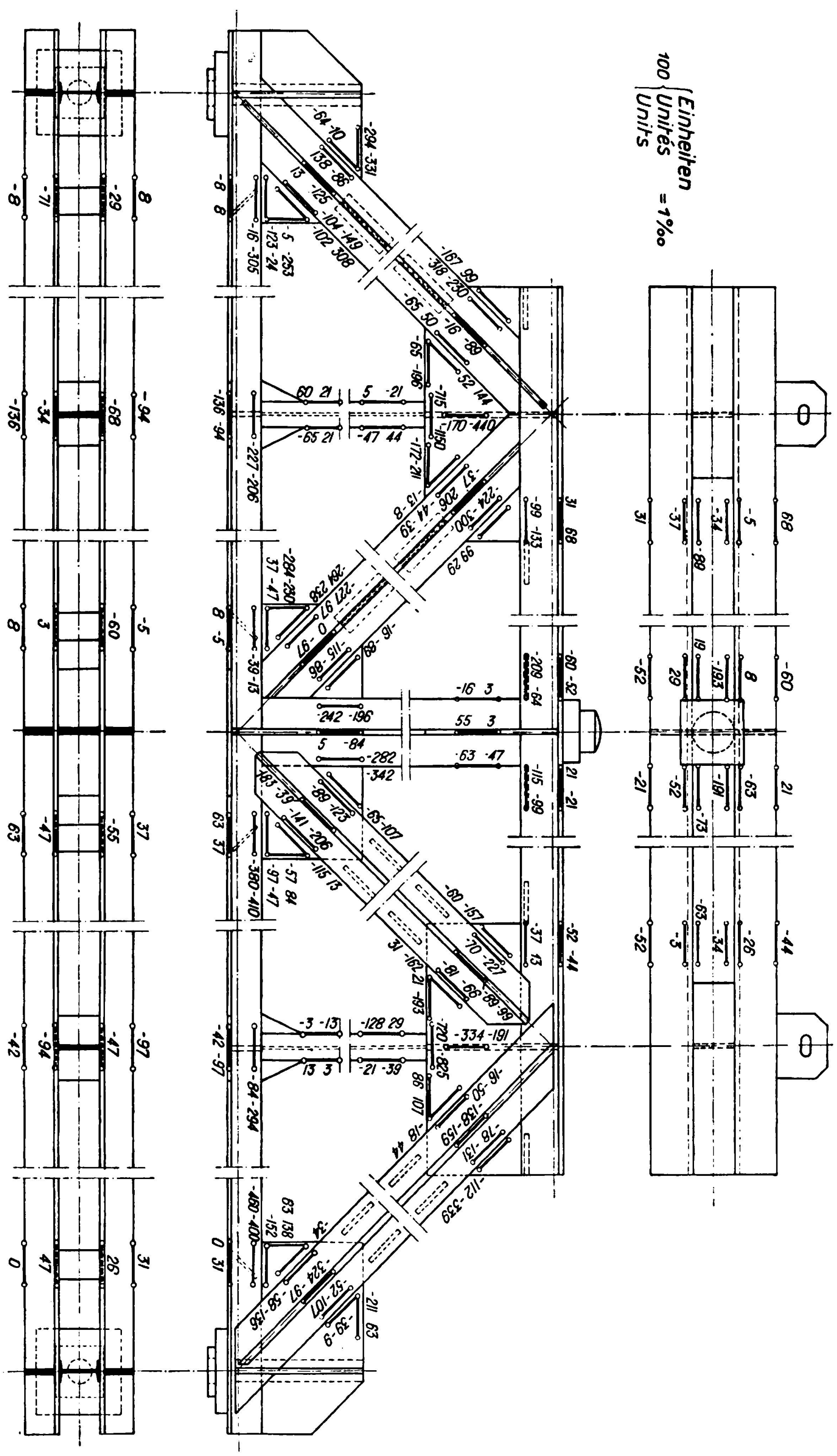

Fig. 1.
Measured shrinkages.

the positive pole, were used. The current reached 200 amps. at abt. 27 volts during the welding.

Execution of the welding.

The welding of the girder was carried out in such a way as to ensure free expansion without any external hindrance to the parts under welding; only when welding the end diagonals this was no more possible as the girder had finally to be joined together.

At first, every member of the girder composed of several pieces was welded together, beginning with the welds in the middle and allowing expansion on both sides. The welding was then continued symmetrically from the middle.

The same order was followed when welding the whole girder. In this way we tried to reduce reaction stresses due to hindrance of free expansion of the hot parts.

In spite of these precautions, remarkable shrinkage appeared. Most striking was the effect of the long welds in the top chord, which caused strong rotations in the chord angles and reduced the free distance between the inside surfaces of these angles from 100 to 96 mm.

It is to be mentioned that — to retain the distance of 100 mm between the chord angles during the welding — rolled sections of 100 mm height were used as distance pieces. The influence of the shrinkage after the cooling down of the finished welding of the top chord was so strong, that it was very difficult to remove the distance pieces. The webs of two of them were buckled and to avoid forcing it out, of a third one the web hat to be burnt.

Measuring of the shrinkage and test results.

The determination of the shrinkage is based on the accurate measuring of the distance between two points in any part of the girder before and after the welding. The difference thus found is mainly due to shrinkage; a small part of it may be due to erection, but — as the fitting together of the different pieces was done very carefully — this could not be considerable.

The changes of length were measured with a Deformator of the Huggenberger type, which allows accuracy up to 0,00261 mm. The distance between the points of the apparatus is 10 cm. This length made it difficult to do any measurements across the seams, so that principally measurements along the seams and the edges of the gussets were carried out.

In each end joint of a member, measurements were carried out along the edges and in the middle, the former were chosen as near as possible to the welds. Other measurements were made in the gusset plates along the welds. Totally there were 212 measuring lengths.

Every length was measured four times; after every measurement the instrument was turned so that its points were changed. The difference between the readings was not to exceed two divisions of the instrument scale = 0,00522 mm. Moreover, the influence of the change of temperature during the measuring was taken into account.

The results of these measurements are given in Fig. 1. The +sign denotes elongation, the —sign shortening. The two values given for each point correspond with both sides of the girder.

The numerical values show big differences, no rule can be derived.

The shrinkages close to the welds are very considerable. They cause bending in the sections so that big changes of length in the outside edges of the latter were measured.

The resulting stresses are not in proportion to the shrinkage, as the latter takes place to the greater part when the material is hot, without practically causing any stresses.

Inspite of this, the shrinkage caused high internal stresses, which lead the material in some places to yielding, but no cracks could be found.

In the fatigue-test, the girder was broken after only 1,4 millions of load repetitions ranging between O and the working load for which the girder was dimensioned, i. e. without raising the limit of loading.

The following conclusions were derived from these tests:

1) The shrinkages do not occur uniformely. No rule can be made for their magnitudes.
2) The shrinkage in the welded trusses reaches very big values, due to the small dimensions of the parts and the relatively big welds. They cause strong rotations in the sections and wavings in the gusset plates.
3) The internal stresses due to the welding can be so high, that they cause the material to yield in some places.
4) The resistance of the welded trussed girders for alternating loads is dangerously reduced by the thermal stresses. The strength of the material to repeated stress is exceeded under the action of the load for which the girder is dimensioned.

The application of the welded trusses requires therefore a lot of care in cases where high dynamic stresses are to be expected.

Summary.

The author describes some of his investigations about the amount of shrinkage. The adopted welding procedure and the mode of taking measurements are explained. The author recommends utmost caution for welded lattice construction if subjected to alternating efforts.