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Behaviour of Structural Members in Case of Welding under Loading

Comportement des éléments de construction lors de soudage sous charge

Verhalten von Bauteilen bei Schweissen unter Last

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SUMMARY

Refurbishment often may require welding at steel members under loading. The deformations that occur differ greatly from those of members welded without loading. Such deformations have a great influence on the ultimate load of reinforced compression bars. The temperature field caused by welding plays an important role. For this reason investigations of the temperature field, the deformations and the structural behaviour of reinforced members have been carried out.

RÉSUMÉ

Lors d'assainissement d'ouvrages, il est souvent nécessaire d'effectuer le soudage des éléments de construction sous charge. Les déformations qui en résultent sont très différentes de celles apparaissant dans des éléments de construction soudés sans charge. Les déformations de ce genre exercent une grande influence sur la charge limite des barres comprimées renforcées. Le champ de température par suite du soudage y joue un rôle important. Des études ont été réalisées sur le champ de température, les déformations qui en résultent et la capacité de charge des éléments de construction renforcés.

ZUSAMMENFASSUNG

Bei der Sanierung von Bauwerken ist es oft erforderlich, an belasteten Bauteilen zu schweissen. Die dann auftretenden Verformungen unterscheiden sich wesentlich von denen geschweisster Bauteile ohne Belastung. Derartige Verformungen haben z.B. einen grossen Einfluss auf die Traglast verstärkter Druckstäbe. Eine wichtige Rolle spielt dabei das Temperaturfeld infolge Schweissen. Aus diesem Grund wurden Untersuchungen des Temperaturfeldes, der daraus resultierenden Verformungen und des Tragverhaltens verstärkter Bauteile durchgeführt.

1. INTRODUCTION

Refurbishment often may require welding at steel members under loading. The deformations occurring differ greatly from those of members welded without loading. Such deformations have a great influence on the ultimate load of reinforced compression bars. The temperature field caused by welding [1,2] plays an important role.

Neither design codes nor the standard publications known to the authors include design rules in case of refurbishment by welding. Consequently the engineer depends on the unloading of the corresponding structural members (often being expensive and extensive).

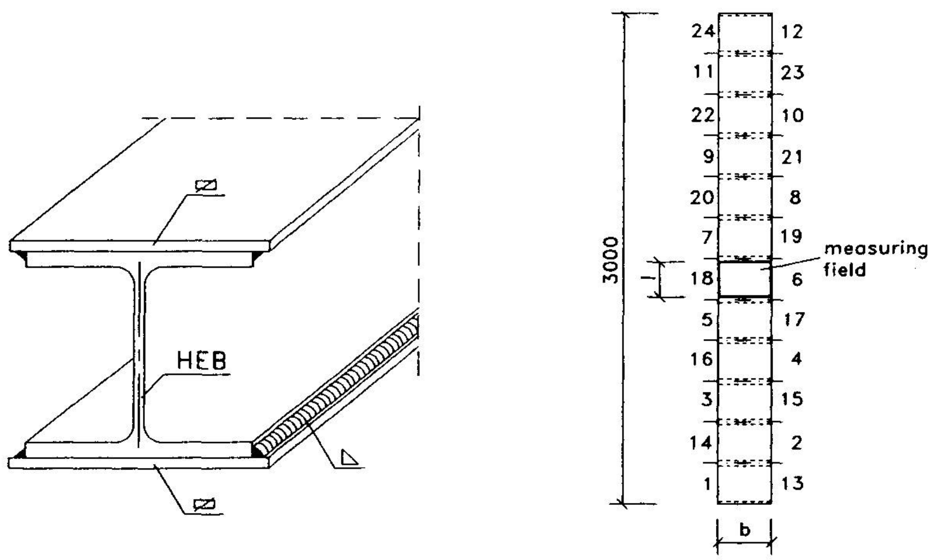
Therefore investigations of the temperature field, the deformations and the structural behaviour of reinforced members have been carried out at the Chairs of Steel Structures of the Technical Universities of Cottbus and Bochum [5].

2. TESTS

2.1 Measurements of the temperature field and deflections caused by welding

Beams and columns (HE 120B resp. HE 200B) of 3 m length were reinforced by welding (E-manual) of cover plates (90 x 10 and 150 x 10 resp. 170 x 10 and 230 x 10 mm) on the upper and/or lower flange (Fig.1). The thickness of the welds was 4 mm for girders resp. 5-6 mm for columns. Girders and columns were distinguished according to their different welding positions and speeds.

The temperature at the surface of the upper cover plate of the specimen was measured by thermovision (measuring field in Fig. 1), additional temperature measurements at selected points were carried out by thermal elements. Moreover the deflection was measured at 11 points equally arranged over the full member length. Three test specimen were available for each cross-section. Altogether 12 tests on columns and beams were carried out. The welding sequence is given in Fig. 1 (points 1, 2, ..., 24).



a b

Fig.1 Test specimen. a Perspective, b Top view, measuring field and welding sequence

Fig. 2 shows a typical temperature field obtained by thermovision measurement (1min 55s after ignition of the electrode).

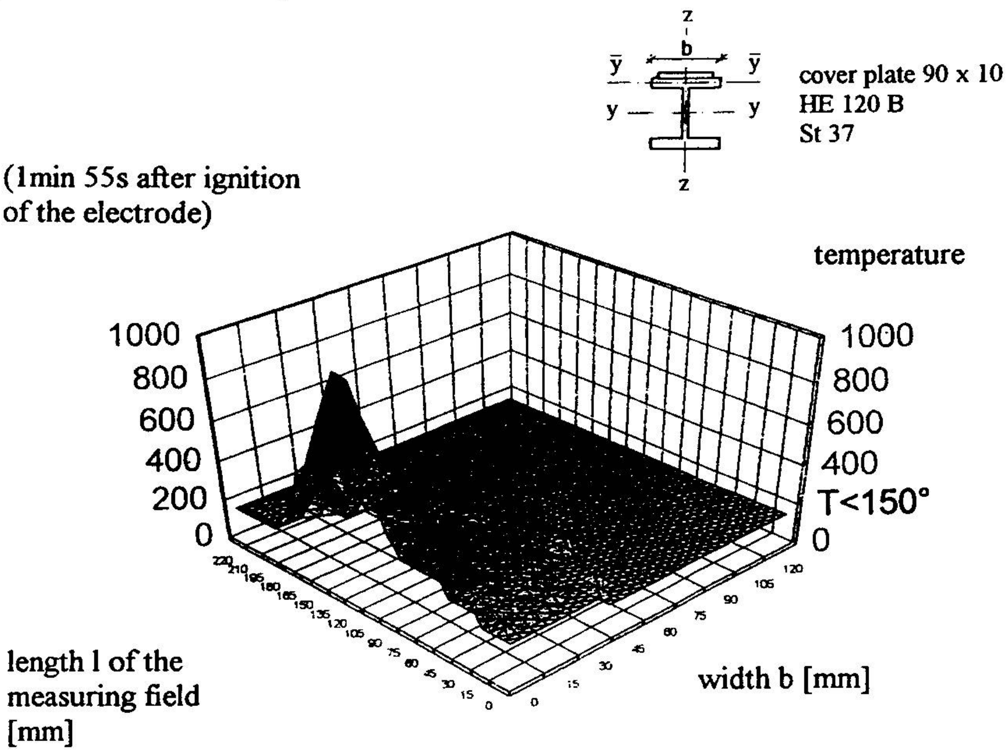


Fig. 2 Temperature field obtained by thermovision

A corresponding stress distribution over the central line of the flange at the cross section is given in Fig. 3.

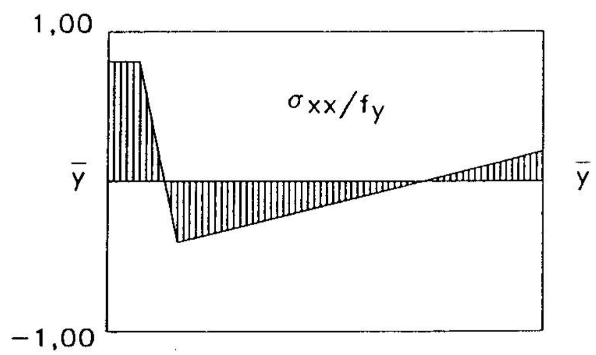


Fig.3 Typical stress distribution

Fig. 4 shows the measured time-variant deflection curves of a column (HE200B plus 1 cover plate 230 x10 mm) during welding (a) and cooling (b).

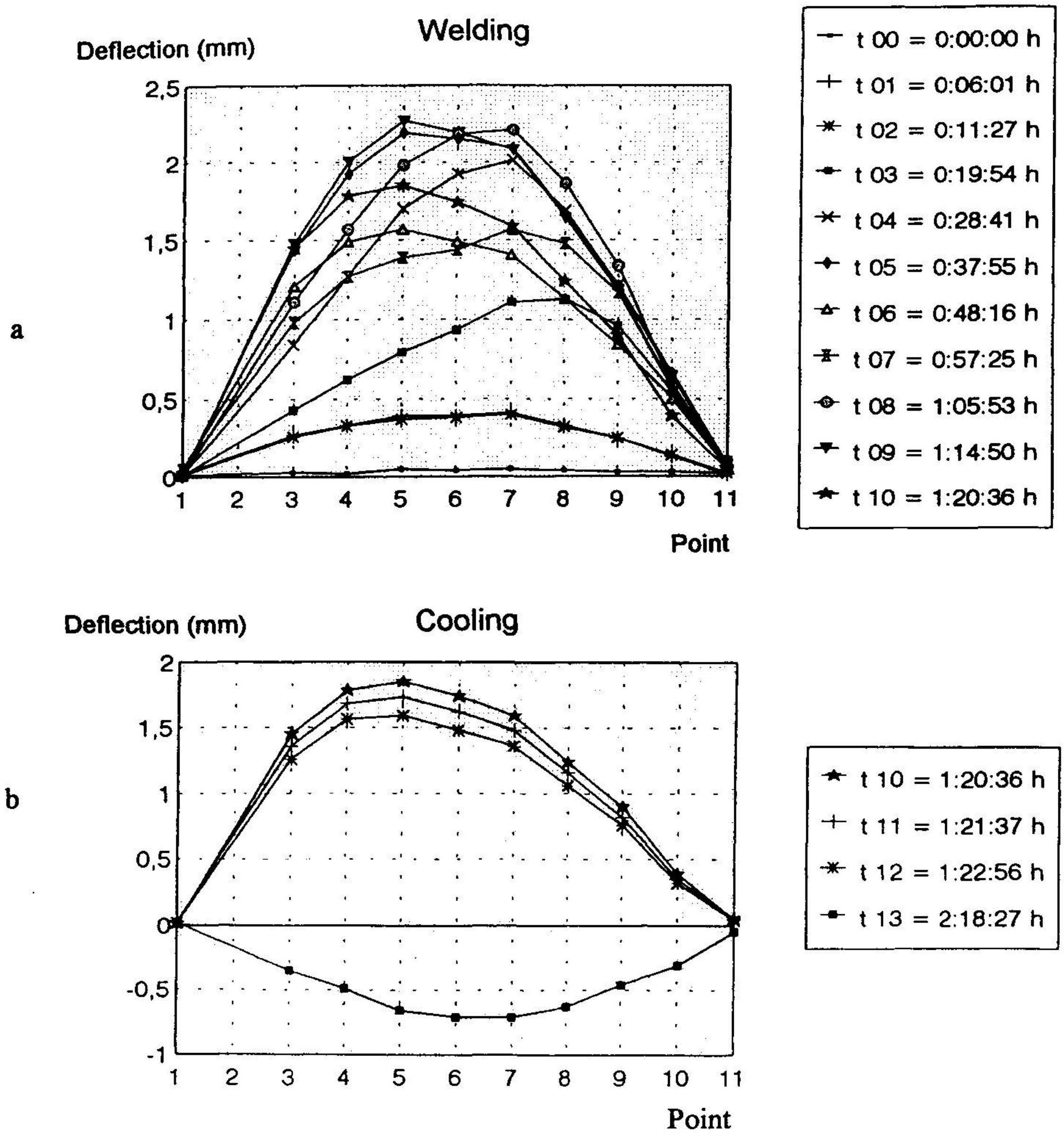


Fig. 4 Deflection curves for a column

The thermovision is a proper means for the measurement of temperature fields. The main results of these investigations are:

- the distribution of energy between the profile flange and cover plate influences greatly the temperature field emerging, the amount of energy in the web may be neglected.
- the heat flow in the cross section occurring vertically to the contact cover plate-profile is of secondary importance.
- the temperature distribution measured corresponds sufficiently with the source method [1,2] calculated quasi-stationary.

The bending lines measured and calculated correspond only partly, caused above all by the assumption of the quasi-stationary temperature field. (Notice: The curvatures calculated from the temperature field at the discrete profiles of the cross section lead via numerical integration to the bending line).

2.2 Ultimate load tests

In addition, 12 columns (HE 120B) have been investigated in ultimate load tests:

- 2 without reinforcement,
- 4 reinforced by (1 or 2) cover plates (70 x 10) but without loading before reinforcing and
- 6 reinforced by (1 or 2) cover plates and subjected to an excentric (e = 55 mm) compression force of 200 kN before reinforcing.

A typical load-deformation curve for a column consisting of HE120B plus 2 cover plates 70 x 10 mm (sequence of reinforcement: first compression flange, next tension flange) subjected to preloading is given in Fig. 5. It can be observed that welding and cooling lead to a significant increase of deflection at the level of 200 kN.

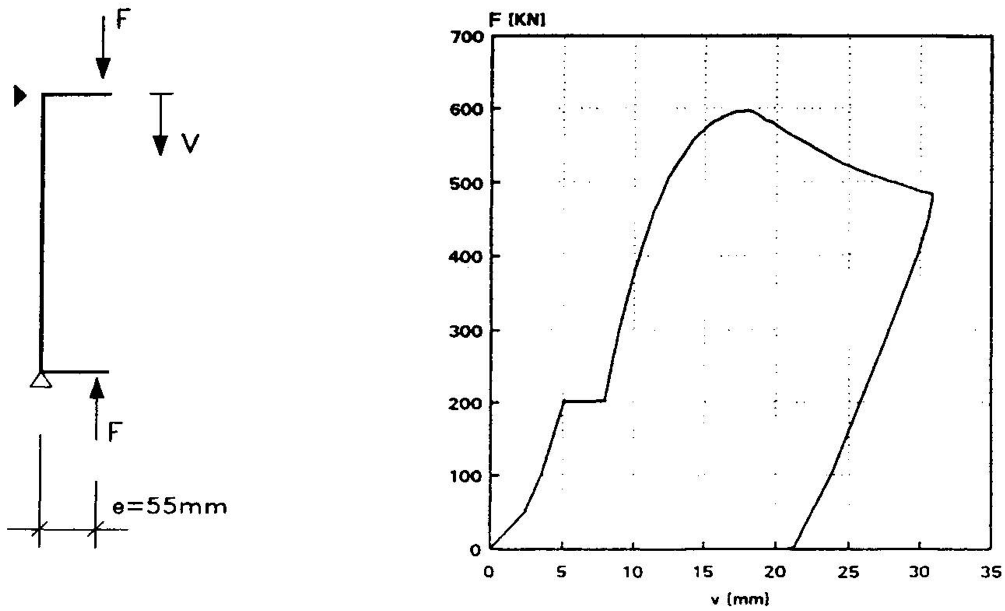


Fig. 5 Load deformation curve

Table 1 contains the load capacities according to German code DIN18800"Steel structures" (without partial safety factors and with real material properties) including the used buckling curves (a,b,c).

Furthermore, the measured load capacities for the cases with and without preloading are presented. For example, the reinforcement of a column by two cover plates leads to an increase of the load capacity from 434.9kN to 648.0 kN, i.e. 49% (without loading before reinforcing) respectively of only 35% (with loading before reinforcing).

Finally the ratios between the calculated and measured load capacities are given. The calculated load capacities of unreinforced columns and reinforced columns without preloading do not differ significantly from the measured ones. In case of preloaded reinforced columns the measured load capacities are up to 10 % below the calculated ones. Welding stresses and deformations are the reason for that. Even a change of the relevant buckling curve (from b to c) is unsufficient.

Table 1: Comparison between calculated and measured load capacities

Column	Calculated load capacity R_c (kN), buckling curve	Measured load capacities R_m(kN) and R_c/R_m ratios without preloading	with preloading
without reinforcement	426.9 (a)	434.90 1.02	
one-sided reinforced	574.0 (b) 553.5 (c)	592.40 1.03 1.07	548.20 0.95 0.99
double-sided reinforced	651.8 (b) 631.4 (c)	648.00 0.99 0.97	587.10 0.90 0.93

3 CONCLUSION

From the current point of view a structure has to be individually calculated for every reinforcing case if you either may not or do not intend to unload it. A PC-computer programme is required for practical use.

At present a computer programme for compression reinforced bars under loading has been developed in Cottbus. The ongoing numerical investigations include:
- the estimation of the temperature field unsteady caused by welding,
- the estimation of strains and residual stresses and finally
- the estimation of the load-deformation curve for the whole member.

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