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ARTICLE

Consistent formulation for LTB of welded beams incorporating an advanced residual stress approach

In the structural stability design of steel structures, the effects of imperfections arising from steel members' fabrication must be adequately accounted for. In the case of welded members, residual stresses have a substantial impact on the structural performance due to the high thermal energy input during production and subsequent non-uniform cooling. In simplified design methods for steel beams, these imperfections are taken into account by assigning the members to buckling curves and the associated imperfection factors. A review of simplified design methods and their structural efficiency for welded members is timely, given the latest results on residual stresses. This paper presents a study on the lateral torsional buckling behaviour of welded steel beams and the subsequent consequences of the findings for simplified design methods. A comprehensive numerical study analysed the load-bearing behaviour of steel beams made of S235 to S690. Residual stresses were taken into account using the residual stress approach according to current standards, as well as a state-of-the-art approach. The numerical study confirmed that residual stresses have a lesser influence on the structural performance of members made from higher steel grades. To take the identified effects into account for structural designs, an adjustment of the imperfection factors is proposed in this paper.

Keywords residual stresses; stability behaviour; lateral torsional buckling; buckling curves; imperfection factor; welded beams

1 Introduction

Steel structures are characterised by their material efficiency and slender design. The ability to create individual welded cross-sections enables cost-effective designs that are customised to specific load conditions. The fabrication process of steel members introduces residual stresses. These stresses are mainly caused by thermal influences, such as those that occur during flame cutting and welding.

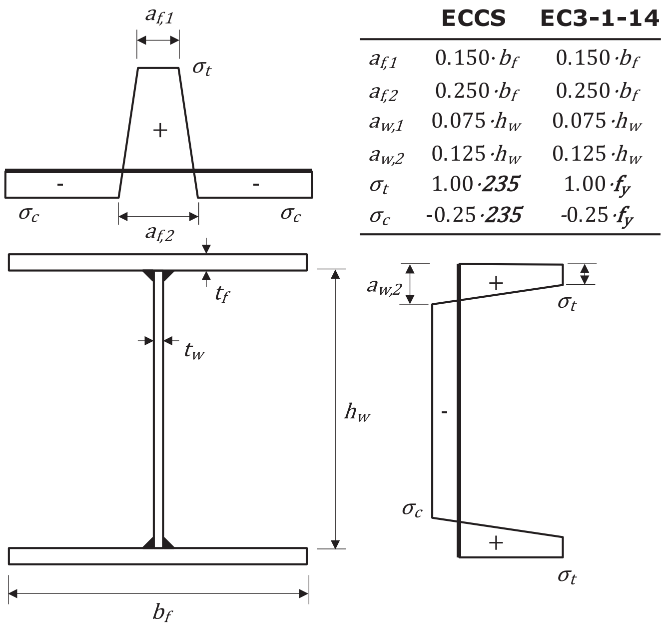
Various studies have explored the distribution of residual stresses, addressing a variety of related issues. Prawel, Morell and Lee [1] compared residual stresses for members produced by shear cutting and flame cutting and concluded that the manufacturing process has a marked effect on the residual stress distribution. Studies presented by Unsworth et al. [2] and Lebastard et al. [3] demonstrated that the cross-section geometry also significantly impacts the residual stress distribution. The influence of the steel grade was, for example, studied by Li et al. [4] and Le et al. [5]. Here, a non-proportional relationship between the yield strength and the magnitude of the residual stresses was detected. Liu [6] focused her studies on the impact of the fabrication processes on residual stresses. Liu concluded that the welding parameters have a minor influence on the residual stress distribution.

Residual stresses play a crucial role in the stability behaviour of steel structures. Lindner [7] observed a reduction of up to 15% of the member capacity, taking into account residual stresses compared to the analysis without residual stresses. Increased computational capabilities nowadays enable advanced simulations and, consequently, detailed analysis of the load-bearing behaviour of steel members. Käsmeier [8] used advanced FEM programs to simulate the load-bearing behaviour of welded members in flexural buckling and lateral torsional buckling. Käsmeier showed that residual stresses influence the development of the yield zones and thus the stability behaviour of members. Yun et al. [9] investigated the influence of residual stresses on the flexural buckling behaviour of welded columns with homogeneous or hybrid I-sections. Based on the finding, a new design approach for flexural buckling was proposed using a yield strength-dependent imperfection factor.

Previous investigations have shown that the residual stress distribution depends on the manufacturing process, the cross-section geometry, and the steel grade. The authors developed a novel residual stress model that considers these influences and investigated the influence of residual stresses on the stability behaviour. Investigations into the impact of these findings on simplified design methods of steel members are still pending.

2 Residual stress approaches for welded I-sections

Studies on the stability behaviour of steel members must take into account residual stresses. Residual stress models are generally used for this purpose to avoid



	ECCS	EC3-1-14
a_{f1}	$0.150 \cdot b_f$	$0.150 \cdot b_f$
a_{f2}	$0.250 \cdot b_f$	$0.250 \cdot b_f$
$a_{w,1}$	$0.075 \cdot h_w$	$0.075 \cdot h_w$
$a_{w,2}$	$0.125 \cdot h_w$	$0.125 \cdot h_w$
σ_t	$1.00 \cdot \mathbf{235}$	$1.00 \cdot \boldsymbol{f_y}$
σ_c	$-0.25 \cdot \mathbf{235}$	$-0.25 \cdot \boldsymbol{f_y}$

Fig. 1 Residual stress approaches according to ECCS [10] and EC3-1-14 [11]

the costs of experimental investigations and still enable comprehensive studies.

In recent years, the model according to ECCS publication no. 33 (ECCS) [10] has been widely adopted for welded steel members (see Fig. 1). This model was originally calibrated using members made of steel grades S235 and S355 in the early 1980s. In this approach, tensile residual stresses as a consequence of the welding procedure are modelled with a fixed value of 235 MPa and compensating compressive residual stresses with a fixed value of

$$-0.25 \cdot 235 = -58.75 \text{ MPa} \tag{1}$$

The model according to ECCS was adopted in the current FprEN 1993-1-14:2024 (EC3-1-14) [11]. The adaptation took into account the increasing use of high-strength steels by adjusting the fixed reference value of 235 MPa to the yield strength f_y (see Fig. 1). However, a comprehensive validation of this model, especially for high-strength welded steel structures and current manufacturing methods, has not been carried out.

The authors previously investigated the effect of current manufacturing processes on the residual stresses of mild-steel and high-strength-steel components [12–14]. Based on these investigations, a novel residual stress model was developed for steel members with mono- and doubly symmetrical I-shaped cross-sections (see Fig. 2). The model is applicable for cross-sections with a uniform steel grade as well as hybrid cross-sections with different steel grades of the respective plates. In the novel model, the influences from manufacturing are considered in terms of thermal cuts (TC) or non-thermal cuts (noTC) for the fabrication of the individual plates, resulting in tensile residual stresses or compressive residual stresses at the flange tips. The magnitude of the tensile residual stresses caused by thermal cutting techniques, as well as the welding procedure, corresponds to the yield strength of the respective plate multiplied by the material parameter ε (Eq. (2)). The use of the material parameter ε enables a suitable consideration of the influence of the steel grade on the residual stresses. The effects of the weld thickness are considered when determining the tensile residual stress-affected area. The magnitudes of the compressive residual stresses are to be determined by equilibrium conditions at the respective plates. The simplification of equilibrium conditions per plate enables the application of the model for mono-symmetric and hybrid cross-sections.

$$\varepsilon = \sqrt{235/f_y} \tag{2}$$

For the validation of the novel residual stress model, own experiments as well as an extensive data set from the literature were evaluated. The experimental studies included 12 specimens tested at the University of Coimbra [15] and 13 specimens at the Ruhr-Universität Bochum [16]. The data set from the literature comprised 16 different studies with residual stress measurements on a total of 69 cross-sections. An overview of the dataset is given in [14]. The validation included specimens made of steel grades S235 to S890 with and without thermally cut plates. The flange widths varied between 100 and 430 mm, and the section height between 110 and 830 mm, respectively.

The data set on residual stress measurements was further used to evaluate and compare the residual stress approaches according to ECCS, EC3-1-14 and the novel model [13, 14]. The evaluation demonstrated that the novel residual stress model provides a significantly better approximation of residual stress distributions across cross-sections with varying geometries and steel grades compared to the models according to ECCS and EC3-1-14. With respect to the steel grade, the model according to ECCS tends to underestimate the residual stresses, and the model according to EC3-1-14 tends to overestimate the residual stresses for members made of higher steel grades.

3 Impact of residual stress approaches on the lateral torsional buckling behaviour

The lateral torsional buckling behaviour of steel beams is markedly influenced by residual stresses [7, 8]. To analyse the lateral torsional buckling behaviour, residual stress approaches are usually used in numerical simulations. Since residual stress approaches vary substantially (see Chapter 2), the question arises as to how these approaches affect the stability analyses.

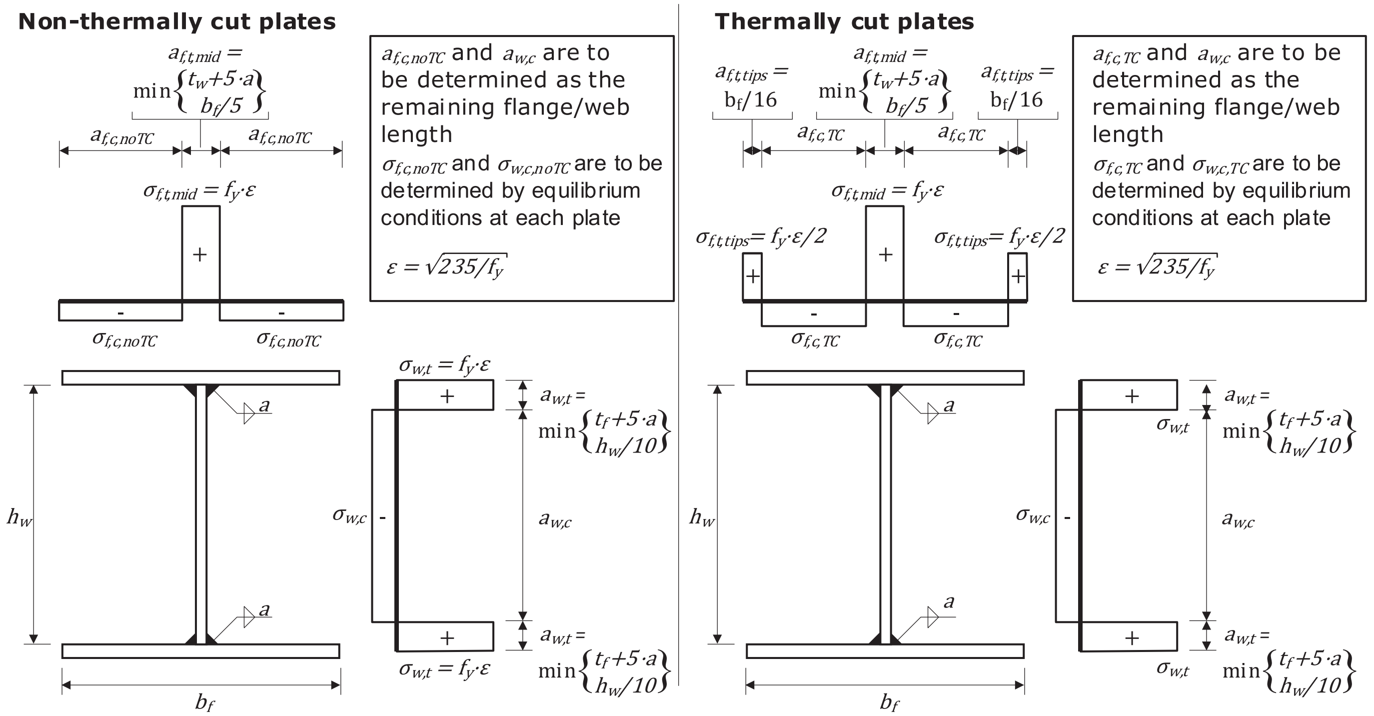


Fig. 2 Proposed novel residual stress approaches for welded I-sections with non-thermally or thermally cut plates [13, 14]

As an example, a welded beam made of steel S690 under constant major-axis bending was analysed for lateral-torsional buckling using the Finite-Element Software ABAQUS. In the analyses, the residual stress approaches according to ECCS [10], EC3-1-14 [11], and the proposed novel residual stress model considering thermal cutting techniques within the fabrication were used (see Fig. 3). The load capacities were determined in relation to the cross-section capacity for relative slendernesses of 0.4–2.0.

The residual stress approaches according to ECCS and EC3-1-14 differ only in the magnitudes of the compressive and tensile residual stresses. For the S690 steel beam, tensile residual stresses of +235 MPa and compressive residual stresses of − 58.8 MPa are taken into account according to ECCS. In contrast, tensile residual stresses of +690 MPa and compressive residual stresses of −175 MPa are applied according to EC3-1-14. This results in a constant ratio of 690/235 = 2.94 comparing the

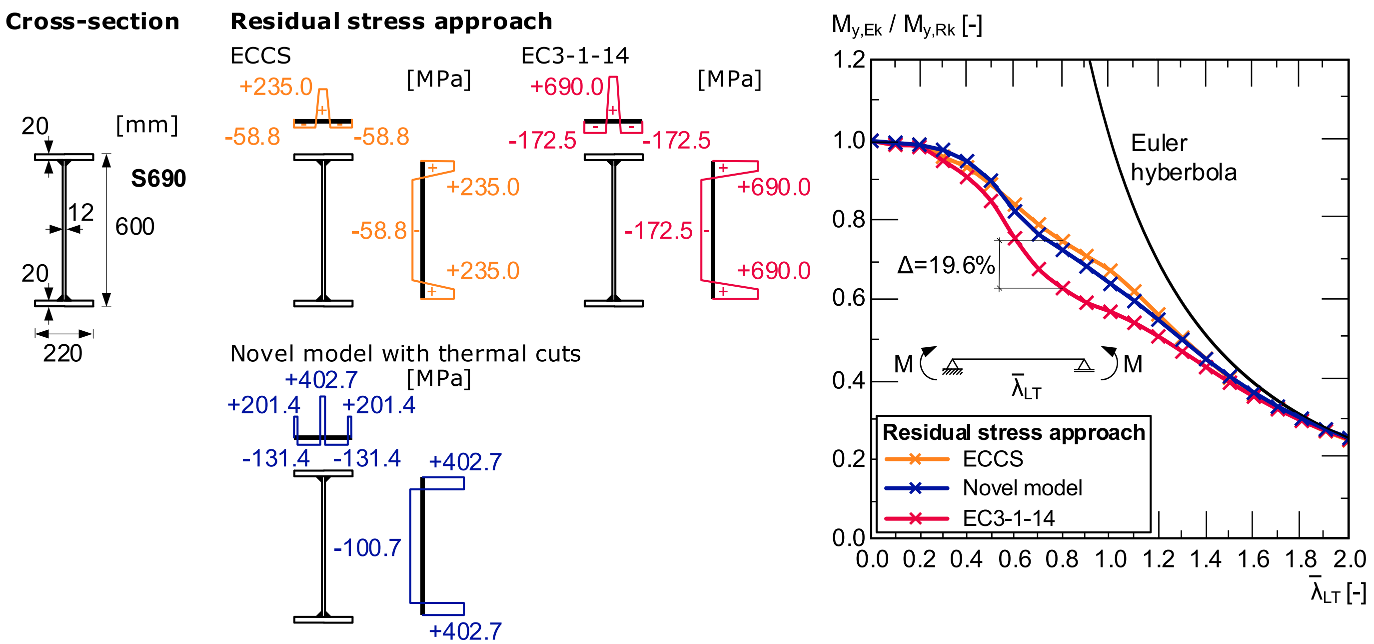


Fig. 3 Influence of residual stress approaches on lateral torsional buckling of a welded beam under constant major axis bending

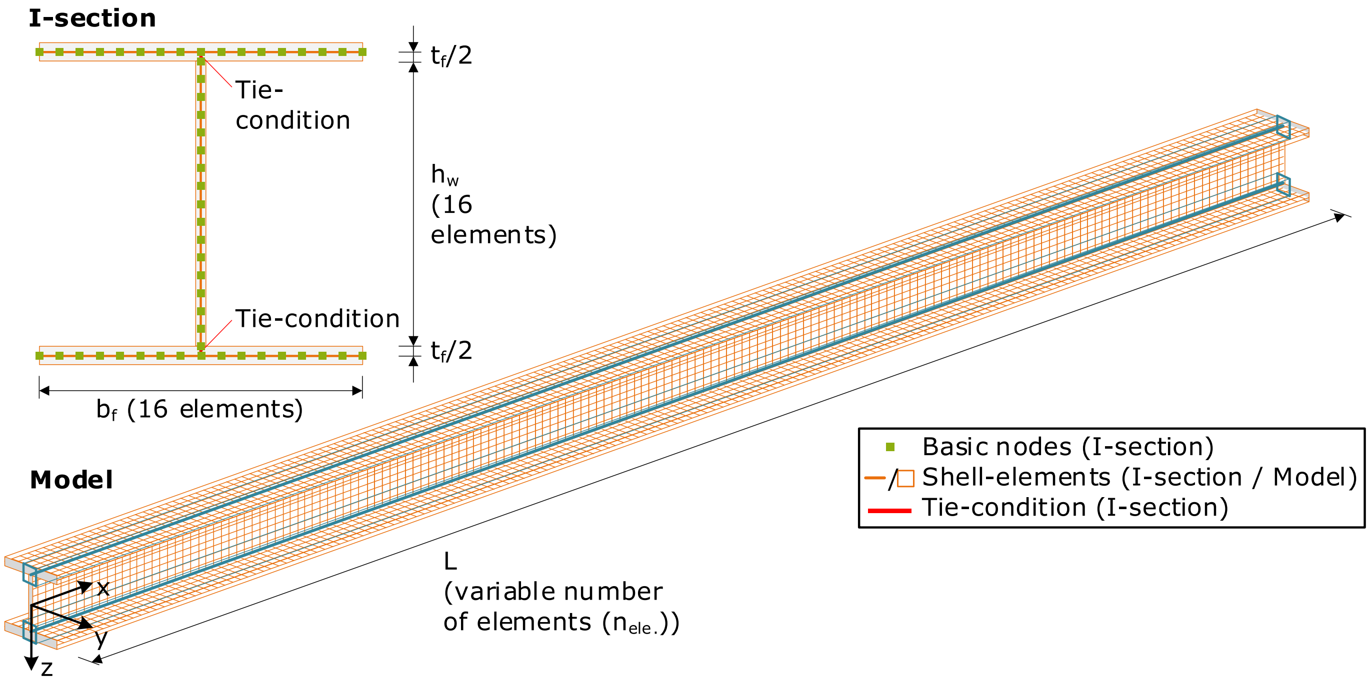


Fig. 4 Numerical model (principle presentation)

residual stress magnitudes of these approaches. In the novel residual stress approach, tensile residual stresses of +402.7 MPa in the area of the welds and +210.4 MPa at the flange tips as well as compressive residual stresses of −131.4 MPa at the flanges and −100.7 MPa at the web are assumed for the investigated S690 steel beam. The magnitude of the residual stresses in this approach is therefore between those according to ECCS and EC3-1-14. However, the contour of this approach differs from the other models, particularly in terms of the tensile residual stresses at the flanges.

The load capacities vary considerably depending on the applied residual stress approach. The highest load capacities were determined using residual stresses according to ECCS, with a fixed value of 235 MPa applied to scale the residual stresses, whereas the lowest load capacities were simulated based on residual stresses according to EC3-1-14. The highest deviation in the load capacities of 19.6% comparing the simulations with these two approaches occurred for a relative slenderness of 0.9. This confirms the sensitive influence of residual stresses on the lateral torsional buckling behaviour, in particular in the medium slenderness range [8], and also shows the significant impact of the magnitude of the residual stresses on the load capacities. Taking into account the novel residual stress model, slightly lower load capacities were determined compared to the approach used in accordance with ECCS. The improved representation of the residual stress distribution and, in particular, the consideration of tensile residual stresses at the flange tips lead to slightly lower load capacities than simulations that consider residual stresses according to ECCS, despite significantly higher residual stress magnitudes. However, it should be noted again that the model according to ECCS was not developed for high-strength steels, whereas the residual stresses for welded members made of high-strength steels are markedly overestimated by the model according to EC3-1-14 [13, 14]. Further studies on the effect of residual stresses on the stability behaviour are provided in [17].

4 Parametric study

A parametric study was conducted using the Finite Element Software ABAQUS. The load-bearing behaviour of welded steel beams with I-sections under uniform bending about the major axis was simulated. The model was designed with a mesh comprising 16 elements spanning the flange widths and 16 elements across the web depth (see Fig. 4). To ensure nearly square-shaped elements, the number of elements along the longitudinal direction of the member was adjusted based on the girder length. A linear elastic-perfectly plastic material model was implemented, excluding strain hardening effects. Geometric bow imperfections were introduced following the relevant eigenmode with an amplitude of $L/1000$. Structural imperfections were incorporated as initial strains, accounting for residual stresses. The numerical model was validated within the framework of two research projects carried out at the University of Stuttgart and Ruhr-Universität Bochum [16, 18].

In the parametric study, four different combinations of plate and weld thicknesses were chosen. Flange plates with thicknesses of 15, 20, 30, and 40 mm were analysed,

Tab. 1 Parameters of the numerical study

	Parameters	Range
Plate and weld composition	t_f [mm]/t_w [mm] / a [mm]	15/8/4; 20/8/4; 30/10/5; 40/15/7
Flange width	b_f [mm]	200; 250; 300; 350
Height-to-width-ratio	h/b_f [-]	1.0; 1.2; 1.4; 1.6; 1.8; 2.0
Symmetry	[-]	Doubly symmetric
Material	[-]	S235; S355; S460; S690
Residual stress approach	[-]	Novel model with thermal cuts; Novel model with non-thermal cuts, EC3-1-14
Stability case	[-]	LTB
Loading		Uniform major axis bending
Slenderness	$\bar{\lambda}_{LT}$ [-]	0.4; 0.8; 1.2; 1.6; 2.0
Total number of simulations		5220

corresponding to web thicknesses ranging from 8 to 15 mm, along with related weld thicknesses. All examined cross-sections were doubly symmetric, featuring flange widths between 200 and 350 mm and height-to-width ratios from 1.0 to 2.0. A height-to-flange thickness ratio of eight or less ($h/t_f \leq 8$) was excluded from consideration to focus on practical cross-section configurations. This range of parameters resulted in a total of 87 distinct welded I-sections. Considering four different steel grades, the residual stress approaches according to the novel model with thermal and non-thermal cuts as well as the approach according to EC3-1-14 [11] and lateral torsional buckling with relative slenderness's from 0.4 to 2.0, resulted in about 5200 load-bearing simulations. The parameters of the study are listed in Tab. 1.

5 Simplified verification methods for lateral torsional buckling

5.1 General

Simplified verification methods are available for assessing the lateral-torsional buckling resistance of beams. These methods are developed based on analytical investigations, experimental studies, or numerical simulations. The different analyses are for configurations with specific boundary conditions, and usually, the datasets are limited. Due to changes to the boundary conditions or the data sets, e.g., as a result of new manufacturing methods, the use of extended materials, or new findings on residual stresses, the simplified design methods must be reviewed.

The simplified verification method for uniform members in bending according to EN 1993-1-1:2022 (EC3-1-1) [19] was developed based on the residual stress approach according to ECCS [10]. However, a new residual stress model was established with the implementation of EC3-1-14 [11]. It is required to verify whether the simplified verification method remains in good agreement with the residual stress approach according to EC3-1-14. Further, the novel model represents the state-of-the-art. The use of new residual stress models requires a review of the design methods and, if necessary, a recalibration. For this purpose, the ultimate loads according to the simplified verification method were compared to the ultimate loads of the parametric study (Chapter 4).

The simplified verification method for the determination of the lateral torsional buckling resistance of uniform members in bending with doubly symmetric I- and H-sections according to EC3-1-1 is given in Eqs. ((3)–(5)).

$$M_{b,Rd} = \chi_{LT} M_{Rk} / \gamma_{M1} \tag{3}$$

$$\chi_{LT} = \frac{f_M}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \bar{\lambda}_{LT}^2}} \text{ but } \chi_{LT} \leq 1.0 \tag{4}$$

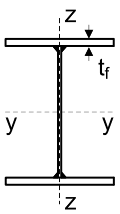
$$\Phi_{LT} = 0.5 \left[1 + f_M \left(\left(\frac{\bar{\lambda}_{LT}}{\bar{\lambda}_z} \right)^2 \alpha_{LT} \left(\bar{\lambda}_z - 0.2 \right) + \bar{\lambda}_{LT}^2 \right) \right] \tag{5}$$

The imperfection factor α_{LT} represents the influence of both geometrical and structural imperfections on the lateral torsional buckling behaviour. Values of the imperfection factor α_{LT} can be chosen depending on the cross-section type and the steel grade. Within the research project STROBE [15], the selection of the buckling curves for welded steel members was revised based on residual stress measurements and the residual stress approach according to ECCS [10]. The proposed imperfection factors are to be implemented with the first amendment to Eurocode 3-1-1 [20]. Tab. 2 contains the proposed imperfection factors α_{LT} for welded I-shaped cross-sections. In case of deviations from the assumed structural imperfections, the evaluation and adjustment of these imperfection factors are reasonable.

5.2 Residual stresses according to EC3-1-14

The agreement between the residual stresses according to EC3-1-14 and the simplified verification method according to EC3-1-1 was analysed. The ultimate loads were

Tab. 2 Proposed imperfection factors α_{LT} for the first amendment to EN 1993-1-1 [20]

Fabrication	**Limits**	**Steel grade**	α_{LT}
	$t_f \leq 40$ mm	S235 to S420	$0.21 \cdot \sqrt{\frac{W_{el,y}}{W_{el,z}}} \leq 0.64$
		S460 up to S700	$0.16 \cdot \sqrt{\frac{W_{el,y}}{W_{el,z}}} \leq 0.49$
	$t_f > 40$ mm	S235 to S420	$0.25 \cdot \sqrt{\frac{W_{el,y}}{W_{el,z}}} \leq 0.76$
		S460 up to S700	$0.21 \cdot \sqrt{\frac{W_{el,y}}{W_{el,z}}} \leq 0.64$

computed using the residual stress approach according to EC3-1-14 within the parametric study. Based on the ultimate loads, the reduction factors were determined (see Eq. (6)).

$$\chi_{\mathrm{LT,FE}} = \frac{\mathrm{ult.}M_{\mathrm{FE}}}{M_{\mathrm{Rk}}} \quad (6)$$

The analytically (EC3-1-1) and numerically (FE) determined reduction factors are confronted in Fig. 5a). The reduction factors according to EC3-1-1 are predominantly on the conservative side compared to the numerical results. However, in the range of $0.65 < \chi_{\mathrm{LT,EC3-1-1}} < 0.85$, it can be seen that almost all reduction factors are on the non-conservative side, with numerous deviations below −10%.

The deviation Δ was calculated as the difference between numerically simulated reduction factors ($\chi_{\mathrm{LT,FE}}$) and analytically determined reduction factors ($\chi_{\mathrm{LT,EC3-1-1}}$) related to the numerically simulated ultimate loads (see Eq. (7)).

$$\Delta = \frac{\chi_{\mathrm{LT,FE}} - \chi_{\mathrm{LT,EC3-1-1}}}{\chi_{\mathrm{LT,FE}}} 100\ [\%] \quad (7)$$

The bars in Fig. 5b illustrate the frequency of the deviations Δ. The horizontal axis shows the deviations Δ, while the vertical axis shows the relative number of deviations within a step width of 2% according to Eq. (8). The curves represent the normal distribution based on the statistical parameters.

$$\bar{n}_i = n_i / \sum n \quad (8)$$

The evaluation resulted in a mean value $\mu = +5.6\%$ and a standard deviation $\sigma = 7.8\%$. This led to a lower 95%-quantile of $q_{95\%} = -7.2\%$ Thus, the simplified verification method leads to a marked number

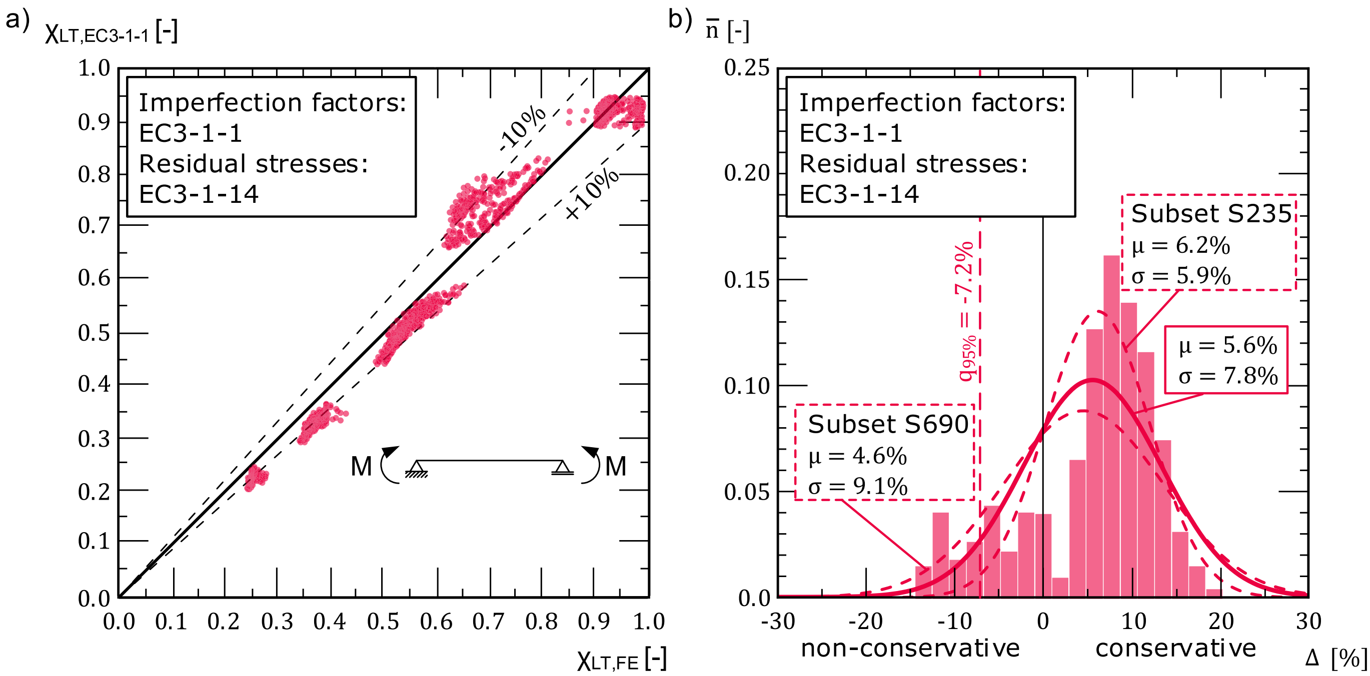


Fig. 5 a) Comparison of analytically and numerically determined reduction factors. b) Deviation between numerically and analytically determined ultimate loads. Imperfection factors in verification method: EC3-1-1. Residual stress approach in simulations: EC3-1-14

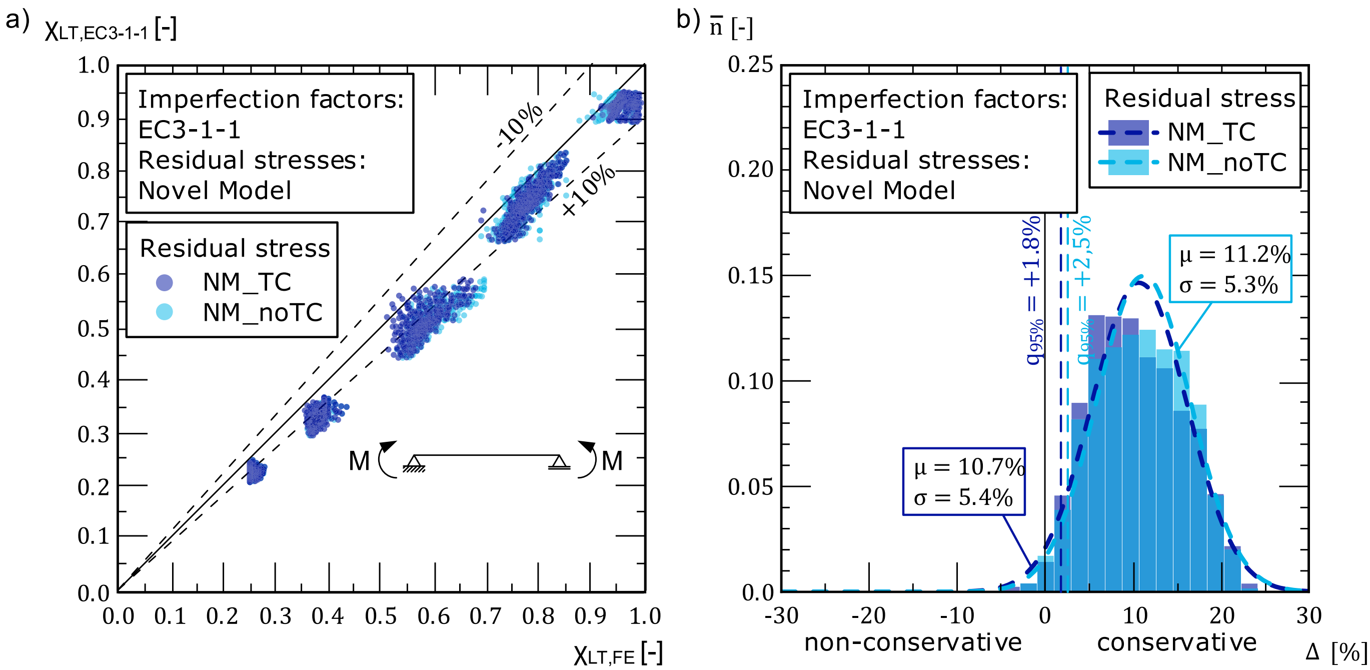


Fig. 6 a) Comparison of analytically and numerically determined reduction factors. b) Deviation between numerically and analytically determined ultimate loads. Imperfection factors in verification method: EC3-1-1. Residual stress approach in simulations: Novel model

of non-conservative results compared with the numerical simulations with consideration of the residual stress model according to EC3-1-14. A focused evaluation of the results showed that the beams made of high-strength steels, in particular, led to non-conservative results, while the beams made of mild steel tended to obtain conservative results.

The evaluation showed that the verification method according to EC3-1-1 results in partially non-conservative results based on a comparison of numerical simulations considering residual stresses according to EC3-1-14, in particular in the range of medium slendernesses. These show, on the one hand, the inconsistency and missing calibration between the residual stress approach introduced in EC3-1-14 and the simplified verification methods in EC3-1-1 and, on the other hand, the over-conservatism of the residual stress approach according to EC3-1-14, especially for high-strength steels.

5.3 Consideration of the novel model for residual stresses

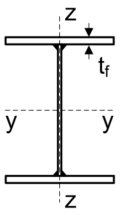
The simplified method according to EC3-1-1 was again evaluated based on the parametric study. The novel model for residual stresses (see Section 2) was implemented within the numerical simulations with consideration of thermal cutting techniques (TC) and with consideration of non-thermal cutting techniques (noTC). With respect to fabrication, both cases, thermally and non-thermally cut plates, were taken into account.

The comparison between numerically and analytically calculated reduction factors (see Fig. 6a) shows that almost all reduction factors according EC3-1-1 are on the conservative side. The deviations are lower than +10% for reduction factors $\chi_{LT,EC3-1-1} > 0.65$ and between approximately 0% and 20% for reduction factors $\chi_{LT,EC3-1-1} \leq 0.65$.

The evaluation of the distribution of deviations (Fig. 6b) resulted in a mean value of $\mu_{TC} = +10.7\%$ and a standard deviation of $\sigma_{TC} = 5.4\%$ taking into account thermal cutting techniques in fabrication, and a mean value of $\mu_{noTC} = +11.2\%$ with a standard deviation $\sigma_{noTC} = 5.3\%$ considering non-thermal cutting procedures. Consequently, this resulted in a lower 95%-quantile of $q_{95\%,TC} = +1.8\%$ (thermal cuts) and $q_{95\%,noTC} = +2.5\%$ (non-thermal cuts), respectively. The statistical parameters of these evaluations are very close for the considered residual stress approaches. In the case of thermal cuts, the beneficial effects on the stability behaviour of the tensile residual stresses at the flange tips are offset by the adverse effects of the resulting increase in compressive stresses at the flanges compared with manufacturing and the resulting residual stresses using non-thermal cutting techniques [13].

The consideration of state-of-the-art residual stress approaches in numerical simulations leads to a good agreement with the simplified verification methods according to EC3-1-1. In particular, for steel beams made of high-strength steel, the more precise approximation of the residual stresses by the novel model results in

Tab. 3 Proposed imperfection factor α_{LT}

Fabrication	Limits	S235 to S700
	$t_f \leq 40$ mm	$0.16 \cdot \varepsilon \cdot \sqrt{\frac{W_{el,y}}{W_{el,z}}} \leq 0.49 \cdot \varepsilon$

simulations with higher load capacities compared to the residual stress approach according to EC3-1-14.

5.4 Adjustments of the buckling curves for lateral torsional buckling of welded beams

For the selection of the imperfection factor α_{LT}, EC3-1-1 differentiates between steel grades S235 to S460 and steel grades higher than S460 up to S700 (see Tab. 2). The investigations of this study have shown that the influence of the steel grade on the residual stresses can be well approximated by the material parameter ε (see Eq. (1)) [13, 14]. Since the imperfection factor α_{LT} represents, inter alia, the influence of residual stresses, a formulation of this parameter using ε is reasonable. Furthermore, the previous investigation (Section 5.3) has shown that the imperfection factor can be adjusted for a more economical design.

A new formulation of the imperfection factor α_{LT} for beams with welded I-sections is proposed in Tab. 3. The formulation of EC3-1-1 was essentially adopted. However, the use of the material parameter ε allows the omission of a steel-grade-dependent case distinction. Further, the first factor was adjusted to 0.16, and the imperfection factor is limited to $0.49 \cdot \varepsilon$. This results in a more economical dimensioning compared with the imperfection factors according to EC3-1-1.

The reduction factors determined with the simplified verification method according to EC3-1-1, but considering the proposed imperfection factors (Tab. 3) were evaluated based on numerical simulations. The residual stresses were taken into account in the numerical simulations with the novel residual stress model.

The adjustment of the proposed imperfection factors leads to an upward shift of the analytically determined reduction factors (see Fig. 7a). All deviations are between −10% and +18%, with most deviations towards the non-conservative side occurring for reduction factors $0.70 < \chi_{LT,Proposal} < 0.90$ and the largest deviations towards the conservative side occurring for reduction factors $\chi_{LT,Proposal} < 0.6$.

The evaluation of the distribution of deviations between analytically determined ultimate loads against the simulations (see Fig. 7b) led to a mean value $\mu_{TC} = +5.4\%$ with a standard deviation $\sigma_{TC} = 5.7\%$ considering thermal cuts, and a mean value $\mu_{noTC} = +5.9\%$ with a standard deviation $\sigma_{noTC} = 5.5\%$ considering non-thermal

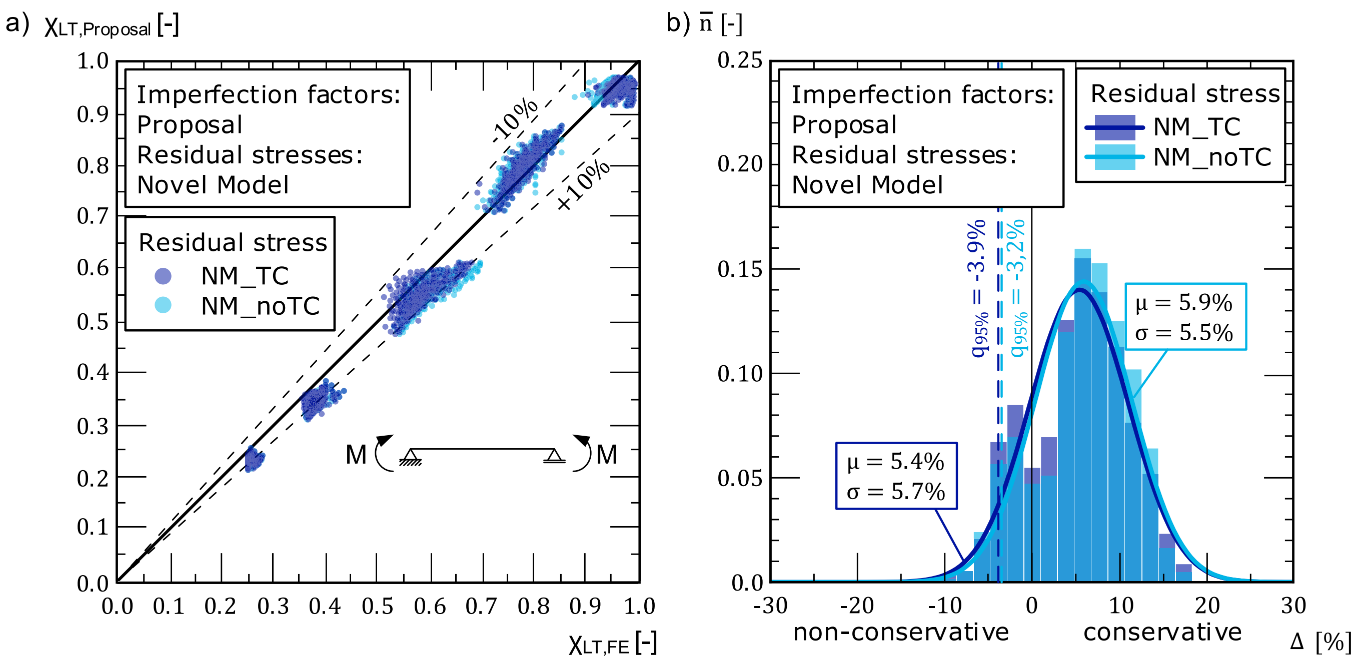


Fig. 7 a) Comparison of analytically and numerically determined reduction factors. b) Deviation between numerically and analytically determined ultimate loads. Imperfection factors in verification method: proposed imperfection factors. Residual stress approach in simulations: Novel model

cuts. Consequently, a lower 95%-quantile of $q_{95\%,\mathrm{TC}} = -3,9\%$ or $q_{95\%,\mathrm{noTC}} = -3.2\%$, respectively, was determined.

The evaluation of the simplified verification method with the use of the proposed imperfection factors based on simulation taking into account the novel residual stress model (Section 5.4) leads to a similar mean value compared to the evaluation of the imperfection factors according to EC3-1-1 based on simulations using the residual stress approach according to EC3-1-14 (section 2.2). However, the standard deviation is markedly reduced, taking into account the proposed imperfection factors. This leads to a reduction of the non-conservative design results ($q_{95\%} = -3.9\%$ instead of $q_{95\%} = -7.2\%$).

Conclusion

This paper has presented findings on residual stresses of welded members with I-shaped cross-sections as well as the impact of residual stress approaches on simplified verification methods.

Analyses of the load-bearing behaviour of welded steel beams in pure bending have detected inconsistencies between simplified verification methods of EN 1993-1-1:2022 [19] and residual stress approaches according to prEN 1993-1-14:2024 [11]. The imperfection factors given in EN 1993-1-1:2022 are calibrated on the residual stress approach according to ECCS pub. no. 33 [10] from 1984. However, in prEN 1993-1-14, a new residual stress approach is introduced. This residual stress approach is not validated and leads to an overestimation of the residual stresses for welded high-strength steel members.

The consideration of the introduced novel residual stress model [13, 14] leads to a good agreement with the simplified verification methods according to EN 1993-1-1:2022.

The use of state-of-the-art residual stress approaches enables the adjustment of the imperfection factors for welded beams with I-sections given in EN 1993-1-1:2022. Firstly, the influences of the steel grade can be uniformly taken into account by the material parameter ε. Secondly, the imperfection factor α_{LT} can be recalibrated. This adjusted imperfection factors based on the novel residual stress model result in a more economic design with fewer deviations to the non-conservative side compared to the current formulations according to EN 1993-1-1:2022 based on the residual stress approach according to prEN 1993-1-14:2024.

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