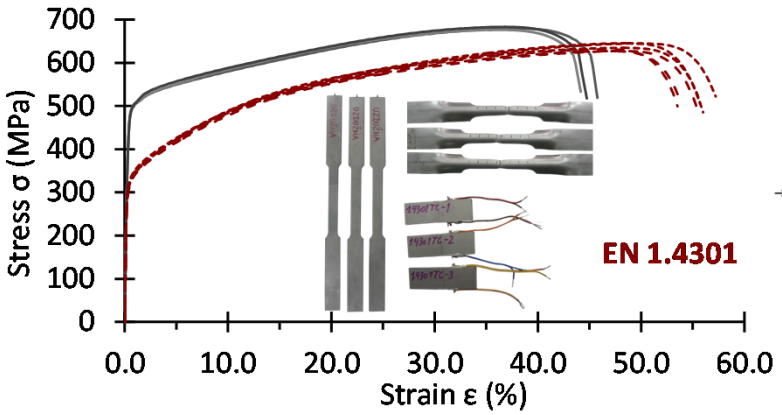
SHEAR STIFFNESS OF CLOSELY SPACED BUILT-UP STAINLESS STEEL COLUMNS

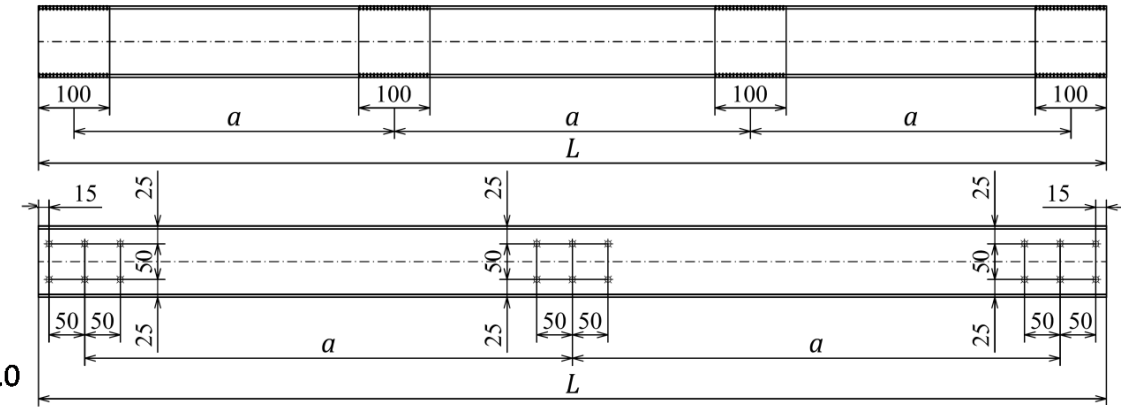
Jelena Dobrić, Zlatko Marković, Dragan Buđevac

Experiment

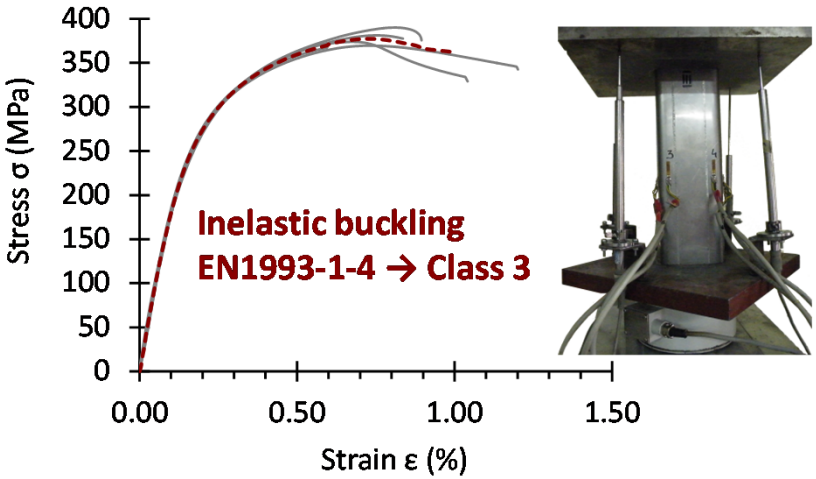
- Material coupon tests

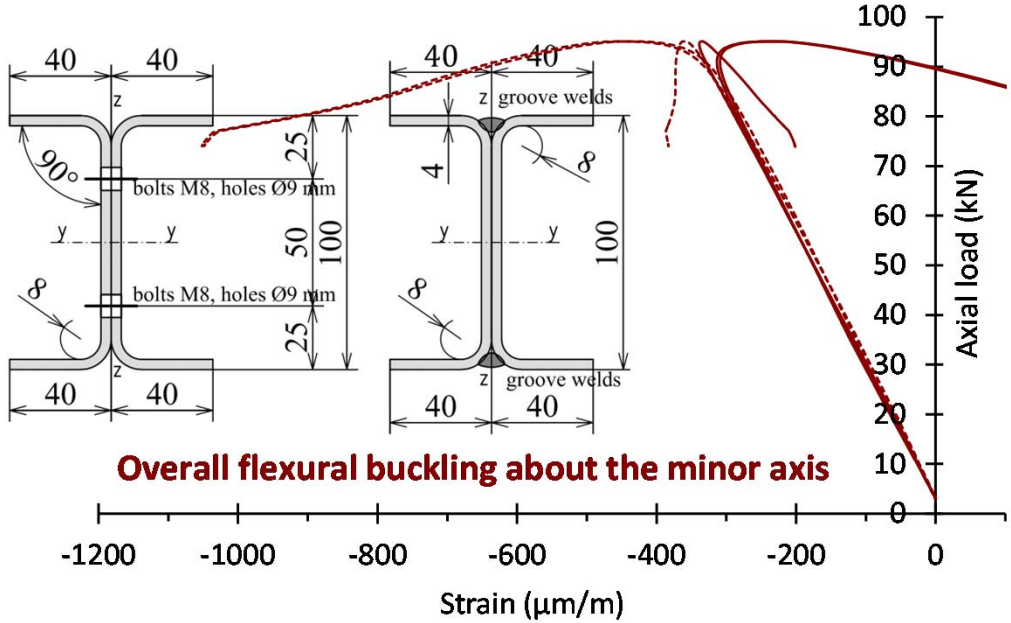


- Flexural buckling tests



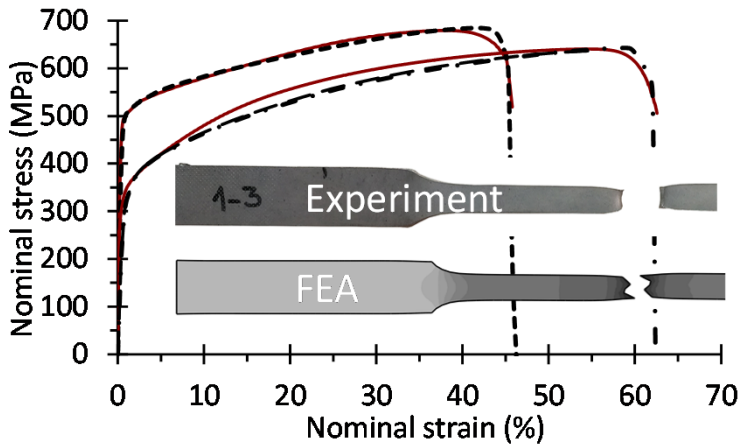
- Stub column tests



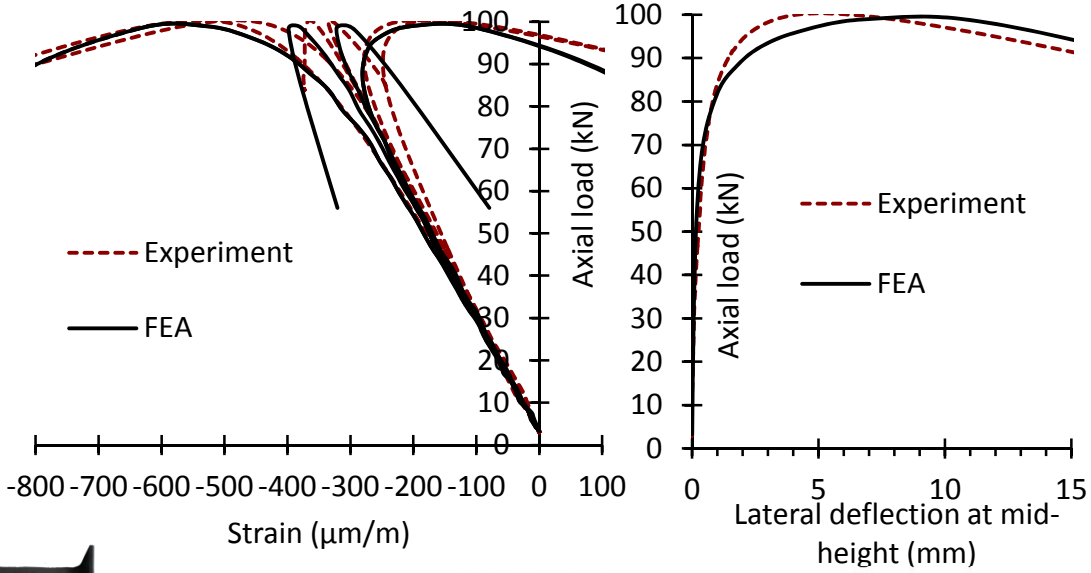


FE simulations

- Material coupon test



- Flexural buckling test



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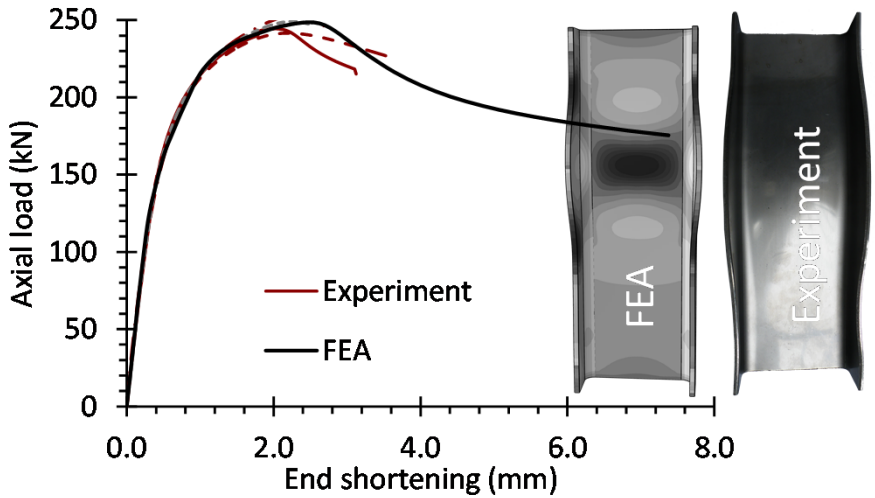
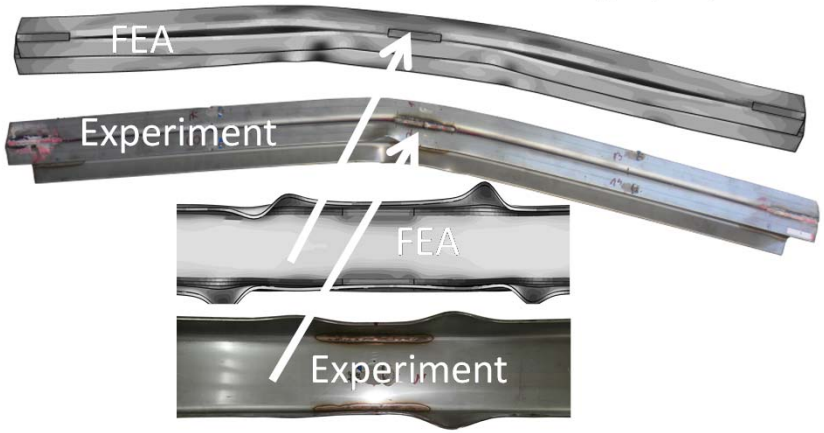
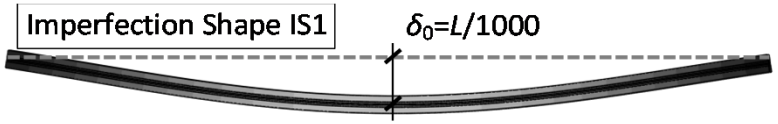
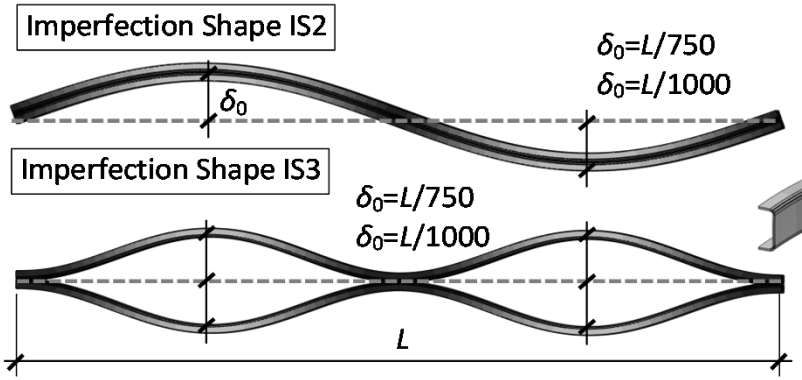


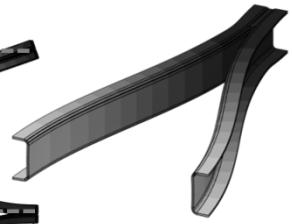


FE parametric studies

- **Main parametric study**
  - Type of interconnection: welded and bolted.
  - Overall slenderness ratio: $\lambda = L/i = 31 – 246$.
  - Chord slenderness ratio: $\lambda_{ch} = a/i_{min} = 15 – 160$.
- **Imperfection sensitivity study**
  - Magnitude and shape of the initial overall geometric imperfections.
  - Built-up columns of intermediate and high overall slenderness of 92, 184 and 246.

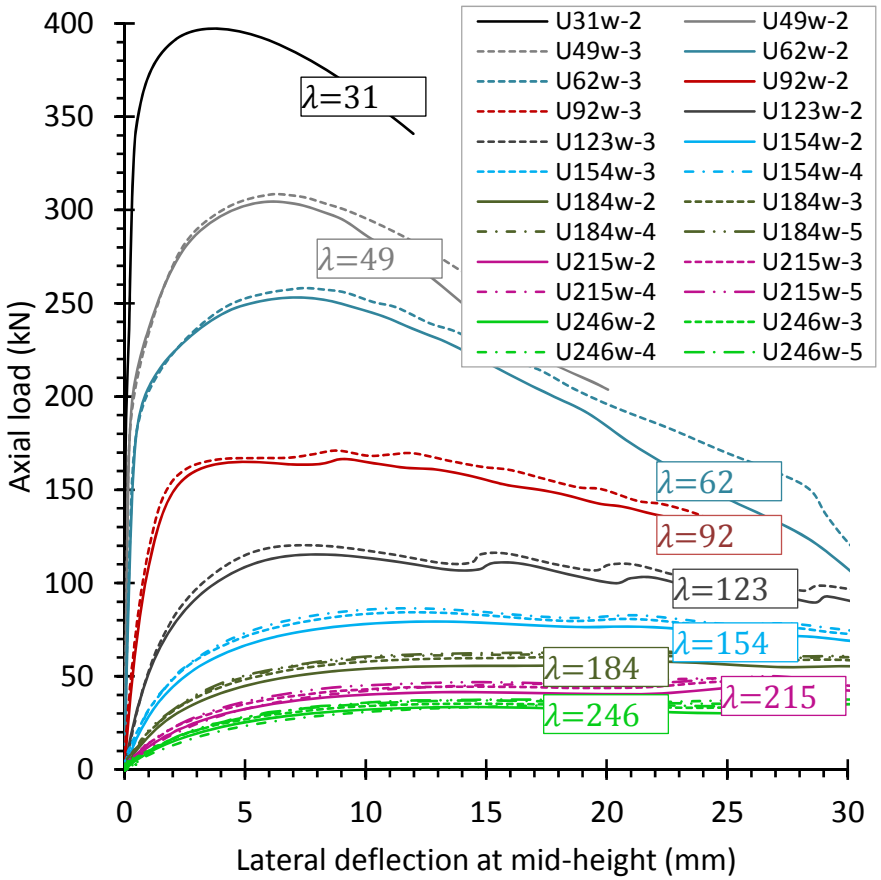




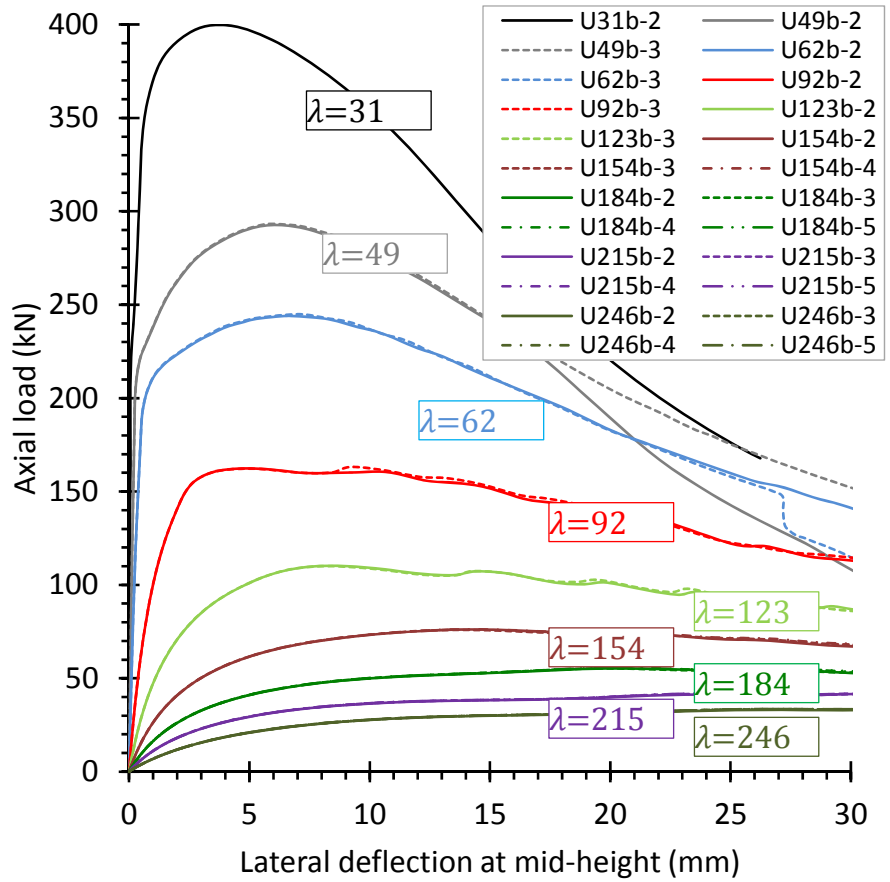


Results of main parametric study

- Built-up columns with bolted interconnections

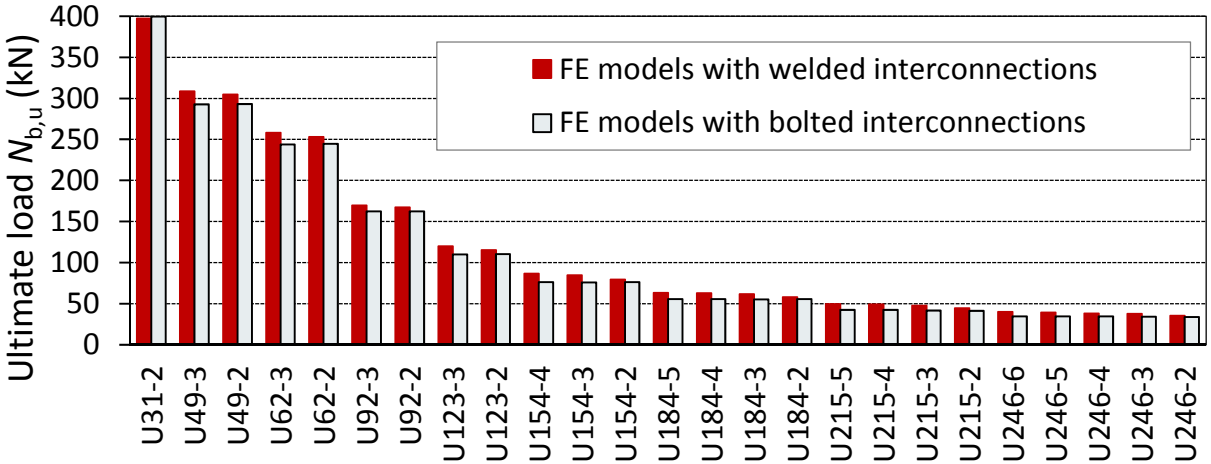


- Built-up columns with welded interconnections

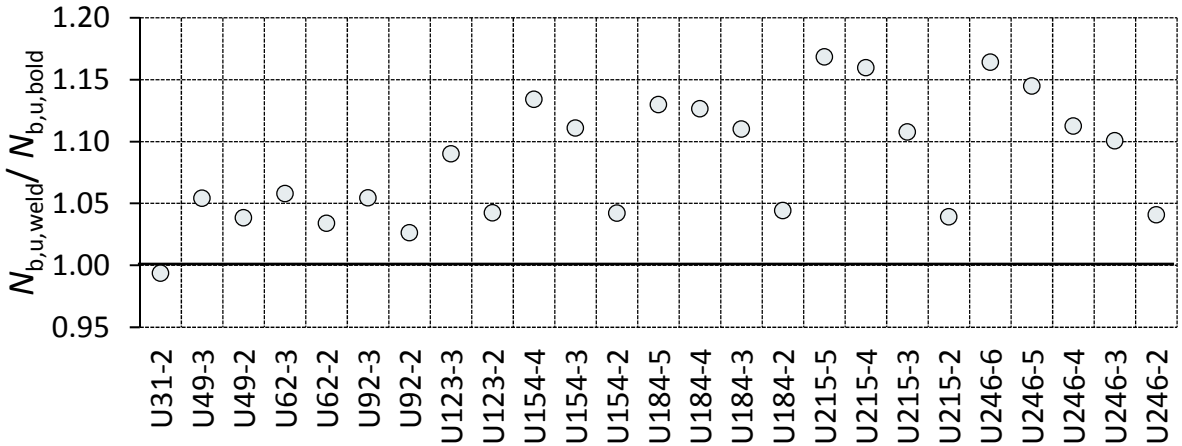


Results of main parametric study

Ultimate buckling loads of FE columns

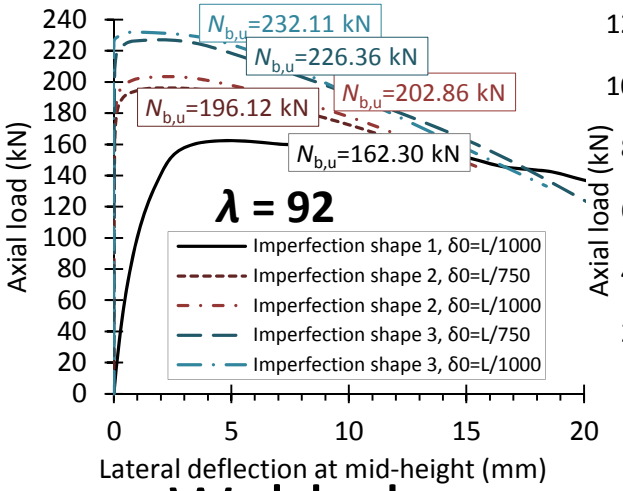


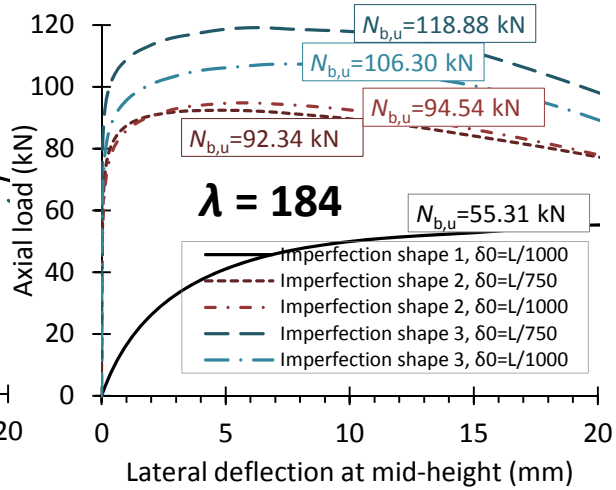
Ratios between ultimate loads of welded and bolted FE columns

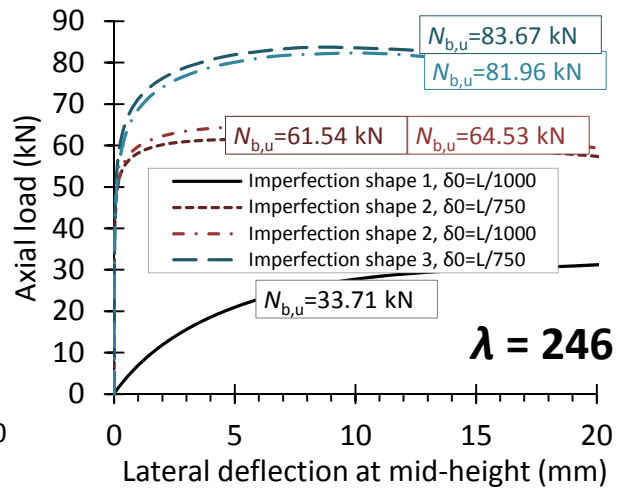


Results of imperfection sensitivity study

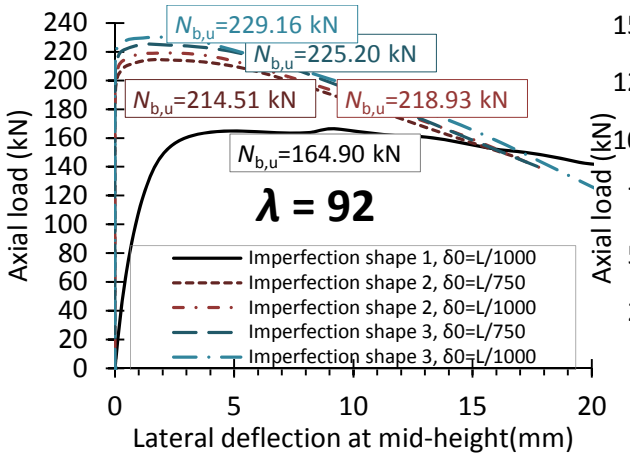
- Bolted built-up columns

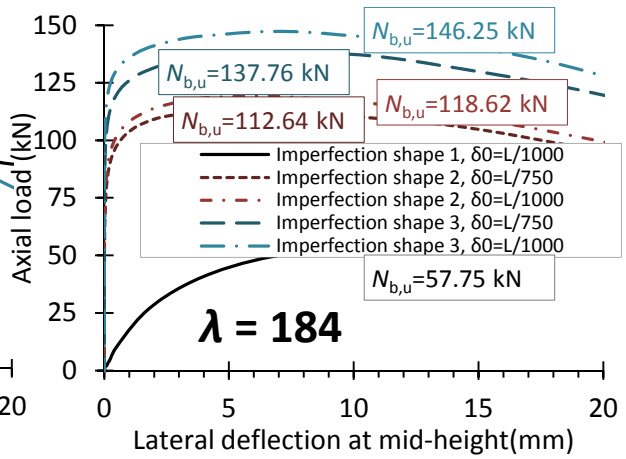


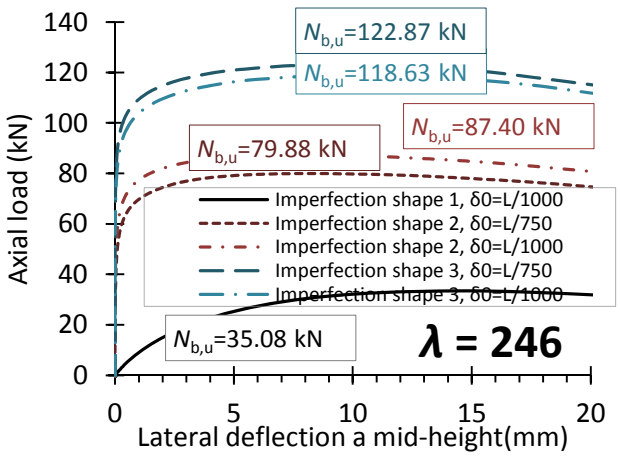




- Welded built-up columns







Results of imperfection sensitivity study

- Quantification of the increase in ultimate buckling loads by changing geometric imperfections

Column	Amplitude	$N_{b,u}^{IS3,\delta_0}/N_{b,u}^{IS1,L/1000}$	$N_{b,u}^{IS2,\delta_0}/N_{b,u}^{IS1,L/1000}$
		Imperfection shape IS3	Imperfection shape IS2
U92b-2	δ_0 = L/1000	1.43	1.25
	δ_0 = L/750	1.39	**1.21**
U92w-2	δ_0 = L/1000	1.39	1.33
	δ_0 = L/750	1.37	1.30
U184b-2	δ_0 = L/1000	1.92	1.71
	δ_0 = L/750	2.15	1.67
U184w-2	δ_0 = L/1000	2.53	2.05
	δ_0 = L/750	2.39	1.95
U246b-2	δ_0 = L/1000	2.43	1.91
	δ_0 = L/750	2.48	1.83
U246w-2	δ_0 = L/1000	3.38	2.49
	δ_0 = L/750	**3.50**	2.28

Design proposal

- The proposed design procedure focuses on pin-ended built-up columns formed from two press-braked channel chords oriented back-to-to back that are directly connected by means of bolts or by welds.
- The design model is synchronized with rules given in parts of Eurocode 3: EN 1993-1-4, EN 1993-1-1 and based on Bleich's analytical criterion:

$$N_{\mathrm{cr,V}} = \frac{\pi^2 EI}{(kL)^2} = \frac{\pi^2 EI}{\left(1 + \frac{\pi^2 I_0}{24 I_{\mathrm{ch}}}\left(\frac{a}{L}\right)^2 + \frac{\pi^2 E I_0}{L^2}\frac{a h_0}{12 E I_{\mathrm{b}}}\right) L^2}$$

Design approaches

- The proposed procedure modifies the general method for the design of axially compressed stainless steel solid columns.
- The procedure introduces an empirical equation for the **equivalent non-dimensional slenderness ratio of a built-up member** instead of the geometric non-dimensional slenderness ratio of a solid member.

Cross-secton class 1, 2 or 3
web $c/t \le 37\varepsilon$; flanges $c/t \le 14\varepsilon$

Built-up columns with bolted interconnections

$$S_V = 2\pi^2 \frac{EI_{ch}}{a^2}$$

Built-up columns with welded interconnections

$$S_V = \frac{24EI_{ch}}{a^2}\frac{I}{I_0}$$

$$N_{cr} = \frac{\pi^2 EI}{L^2}$$

$$N_{cr,V} = \frac{1}{\frac{1}{N_{cr}} + \frac{1}{S_V}}$$

$$\bar{\lambda}_{eq} = \sqrt{\frac{Af_y}{N_{cr,V}}}$$

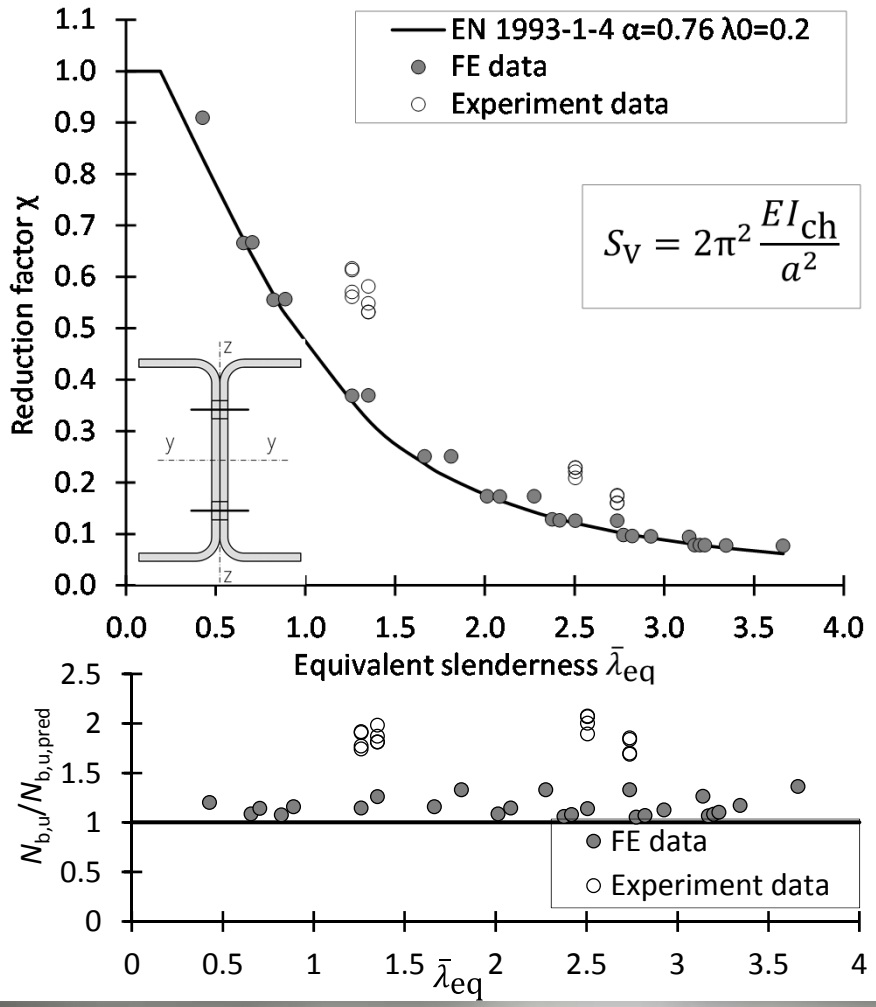
$$\phi = 0.5\left[1 + \alpha(\bar{\lambda}_{eq} - \bar{\lambda}_0) + \bar{\lambda}_{eq}^{\,2}\right]$$

$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \bar{\lambda}_{eq}^{\,2}}}$$

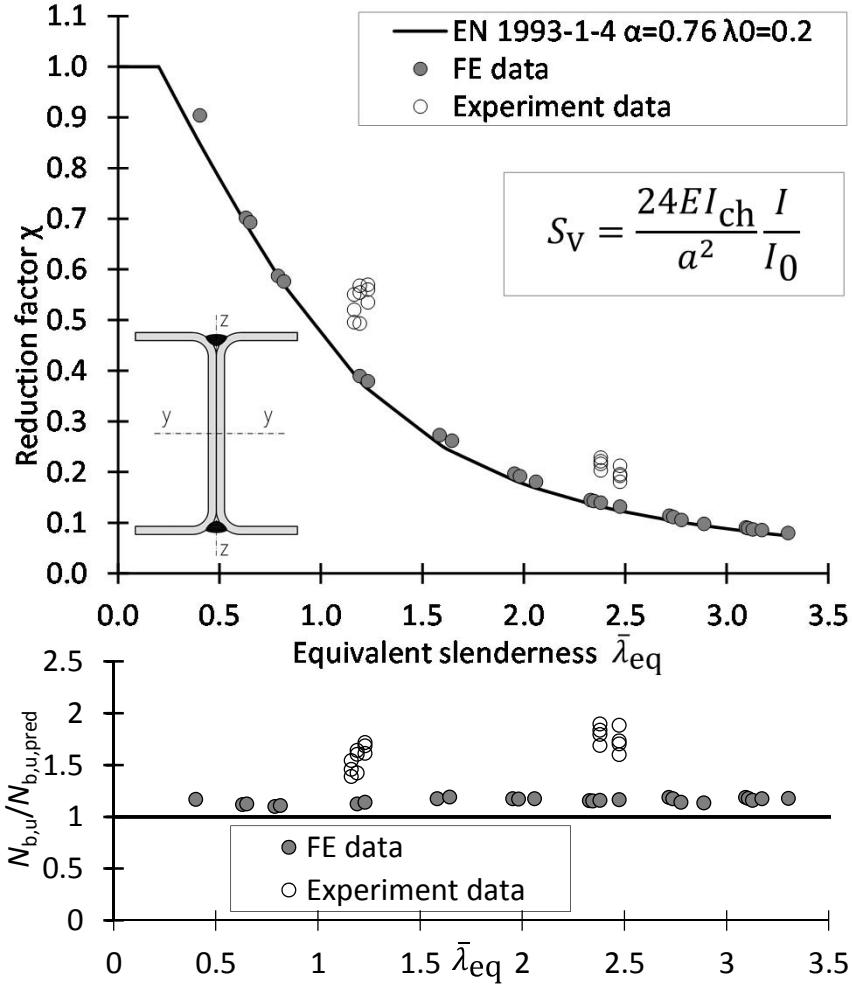
$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}}$$

Assessment of proposed design method

- Built-up columns with bolted interconnections

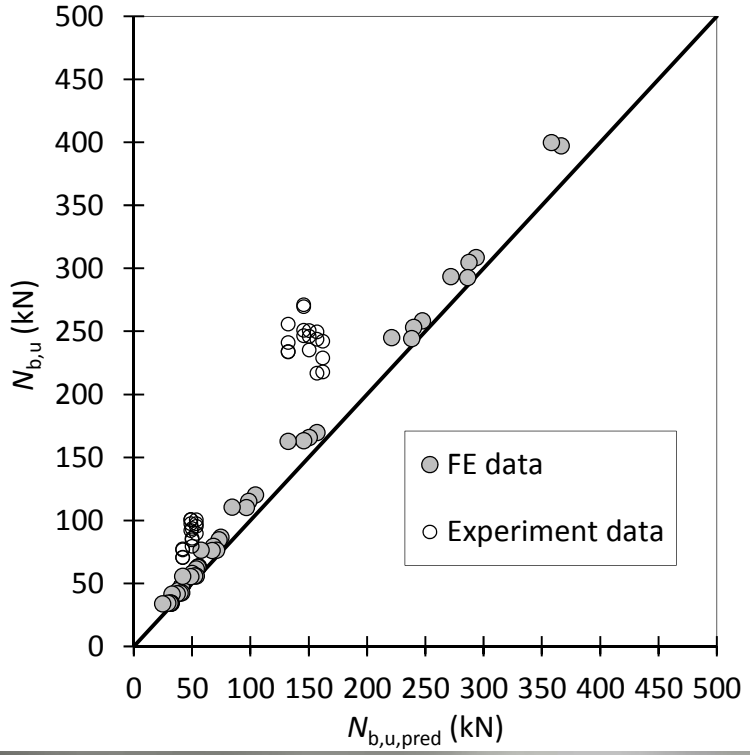


- Built-up columns with welded interconnections



Reliability analysis

Section type	Material	Dataset	No. of experiments / FE data	$k_{d,n}$	b	V_δ	V_r	γ_{M1}
Closely spaced built-up section	Austenitic stainless steel	Experiments	33	3.041	1.693	0.100	0.122	**1.18**
		FE data	50	3.048	1.141	0.060	0.093	**1.13**



Conclusions

1. The type of interconnections, the number of interconnections and initial overall geometric imperfections have a crucial impact on a column's buckling resistance.
2. The influence of the type and number of interconnections significantly vary depending on column slenderness and the distribution and magnitude of the imperfections.
3. The built-up column with welded interconnections exhibits better structural response than that with bolted interconnections.
4. The distribution of imperfections represented as a sine wave of individual chords between interconnections does not lead to the premature failure of individual chords.

Conclusions

5. The proposed design procedure involves two different formulas for shear stiffness provided for built-up columns with bolted and welded interconnections. The flexural-buckling resistance is determined by considering the buckling curve *D* in conjunction with the non-dimensional limiting slenderness of 0.2.
6. The proposed design method extends limit of the chord slenderness ratio-to-overall slenderness ratio up to 65% for both types of built-up columns.
7. The reliability analysis performed on 33 experimental and 50 numerical results indicates a higher value of the partial safety factor in comparison with the codified value of 1.1 in EN 1993-1-4.

Thank you for your attention