Highlight of limitations in analytical methods for cellular beams design

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Introduction

The design of steel cellular beams is well established and will be addressed in the next generation of Eurocodes, particularly in prEN1993-1-13 and prEN1993-1-2 Annex E. However, these standards present limitations that restrict the scope of application of steel beams with large web openings to simply supported configurations, especially concerning global behaviors, such as lateral torsional buckling.

This study presents an analysis of numerical simulations results aimed at identifying configurations where existing analytical methods could be refined or extended.

Lateral Torsional buckling

- Asymmetric 4 points bending configurations
- Analysis of **shear interaction** and **interaction with local failure modes such as Vierendeel mechanism.**

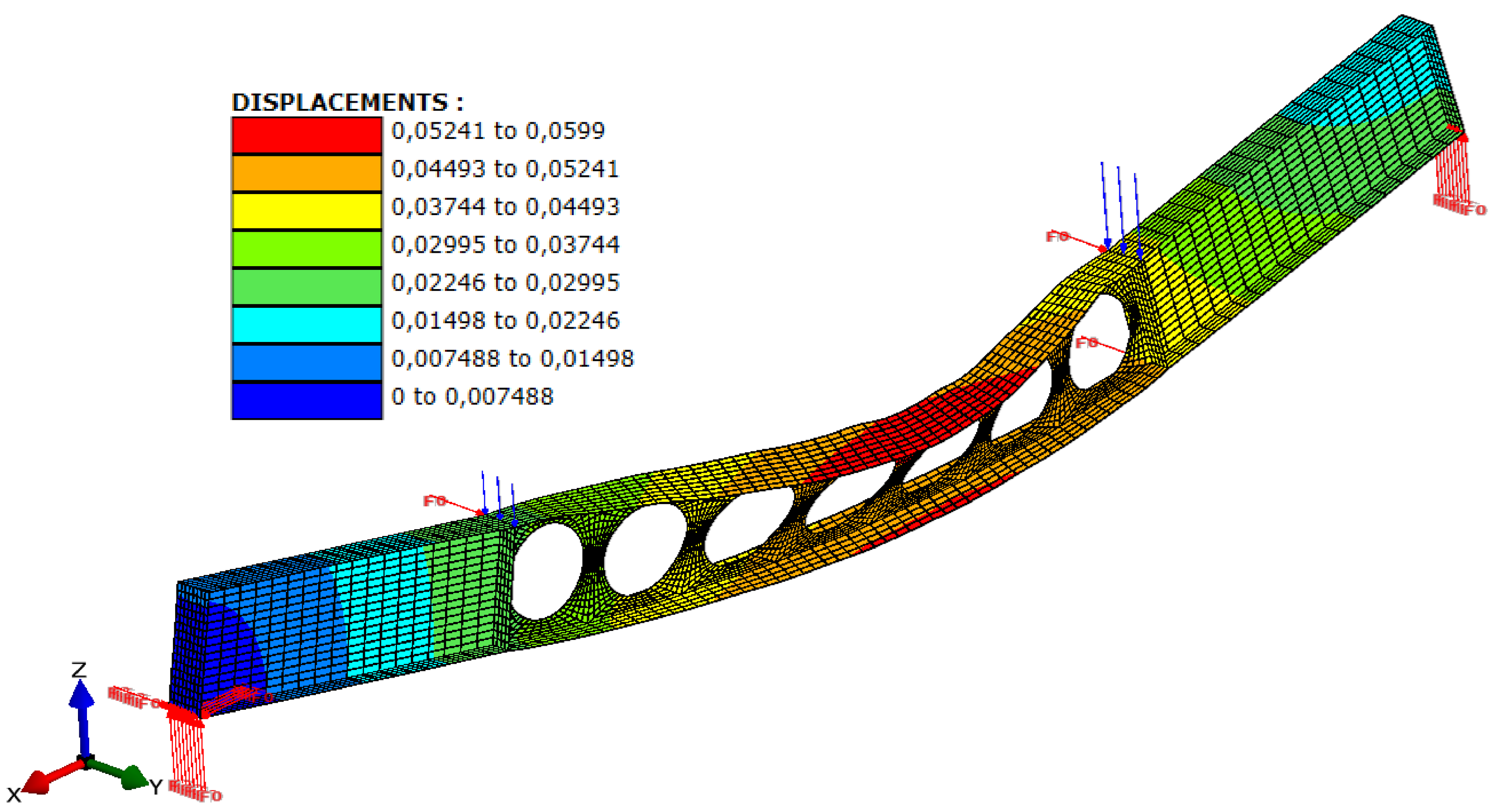

Figure 1. LTB failure (disp. Amplified)

At ambient temperature

	Failure mode	Failure load [kN]
Numerical	LTB	230
Analytical	LTB	148

Table 1. LTB failure load ambient temperature

- The analytical model **underestimates the LTB resistance of the beam by 45%**.

At elevated temperature

Applied numerical T°	Numerical failure load [kN]	Analytical critical T°
400	170	/
500	138	/
550	110	419
600	81	563
620	73	592

Table 2. LTB failure loads (num) and critical T° (an)

- The analytical method does not enable to compare the critical temperatures when temperatures are low (below 500°C) due to the **high safety margin** of the method.

Moment resisting frames

- Results reveal **discrepancies of up to 60% in the predicted LTB failure** load when comparing analytical methods to numerical models (safe side).
- Initial analyses indicate that the primary source of difference is the **shear–moment interaction**
- **More significant influence in cellular beams** than in solid web beams.

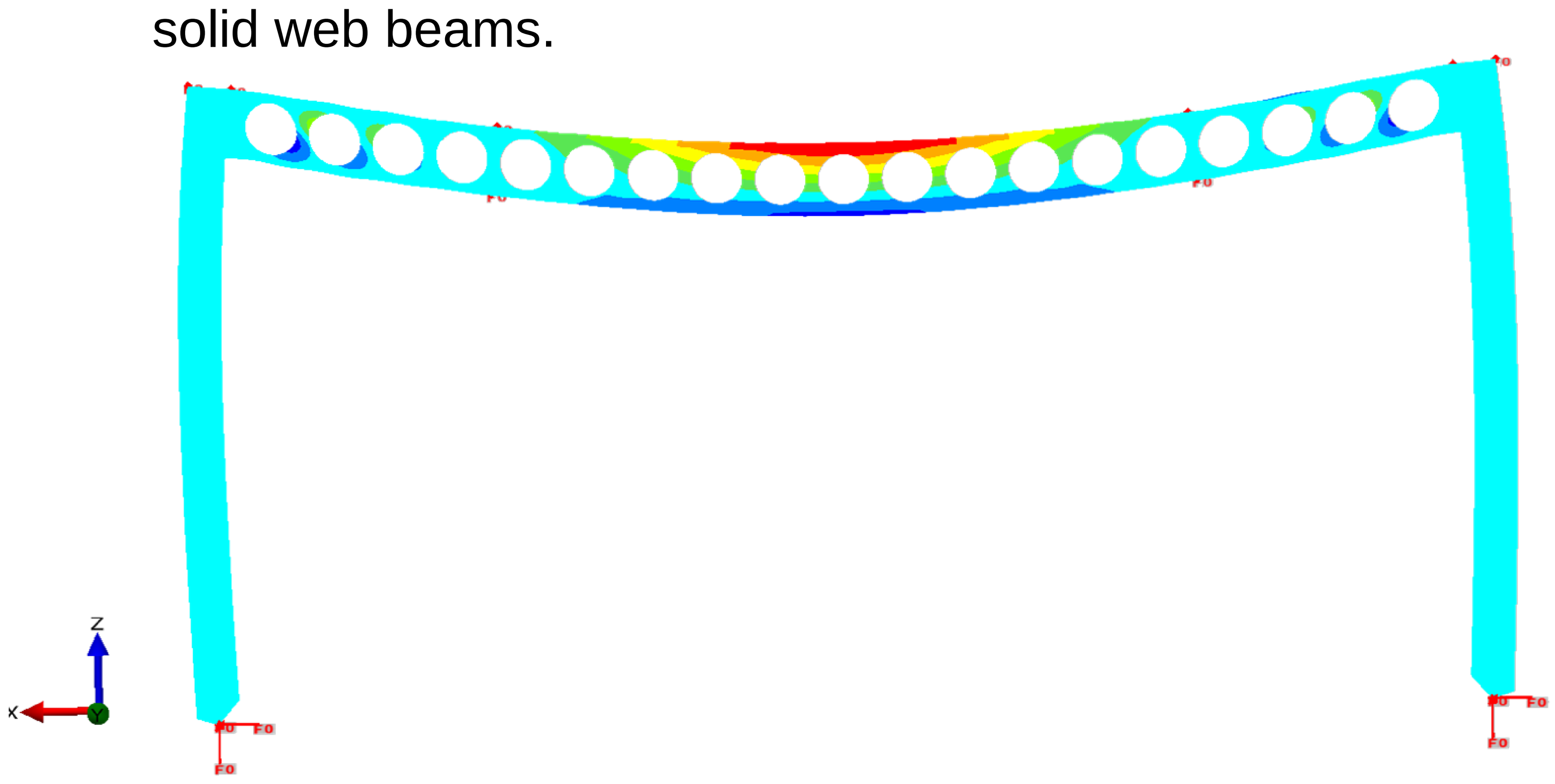

Figure 2. LTB of moment resisting frame(disp. Amplified)

Vierendeel mechanism

Lateral displacement was prevented to target **Vierendeel failure**.

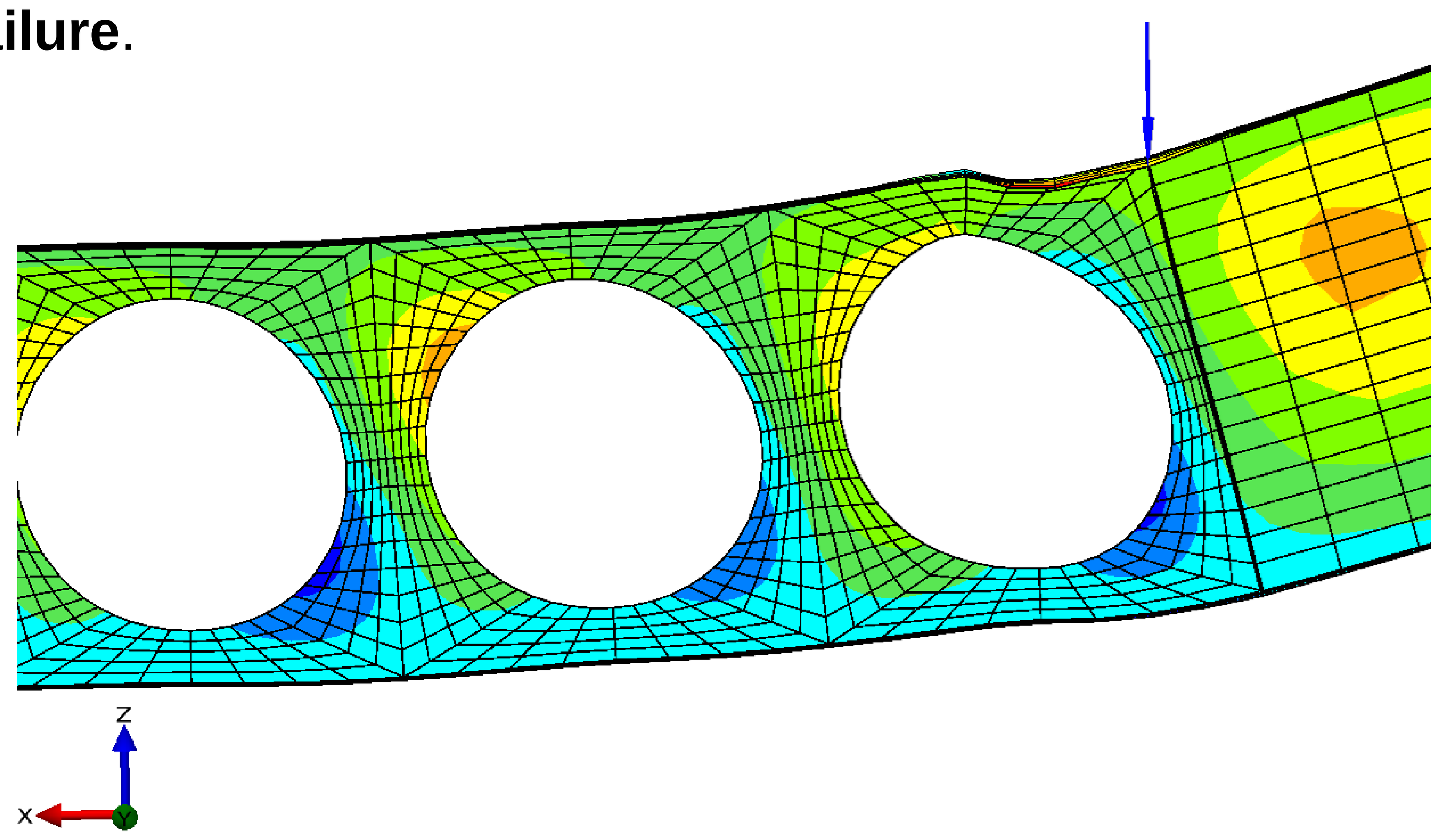

Figure 3. Vierendeel failure (disp. Amplified)

At ambient temperature

	Failure mode	Failure load [kN]
Numerical	Vierendeel	239
Analytical	Vierendeel	210

Table 3. Vierendeel failure load ambient temperature

- **The analytical model underestimates the Vierendeel resistance of the beam by 12%** (considered acceptable).

Note: The vertical stiffener under the point load brings additional resistance to Vierendeel mechanism that is not considered in the analytical approach.

At elevated temperature (500°C)

- The numerical model fails for a load of 170kN. The analytical method predicts a corresponding critical temperature of 520 °C, **closely matching the numerical result.**

Conclusions and perspectives

Global stability design methods, especially **LTB** have been validated for symmetric 4 points bending scenarios. Under asymmetric loading or in moment-resisting frames, they tend to be **overly conservative**. Initial results suggest that **shear–bending interaction**, more critical in cellular beams, is a key factor. In contrast, local failure modes like **Vierendeel show good agreement** between analytical and numerical results. Research will be carried on in RFCS project TAPERFRAME.