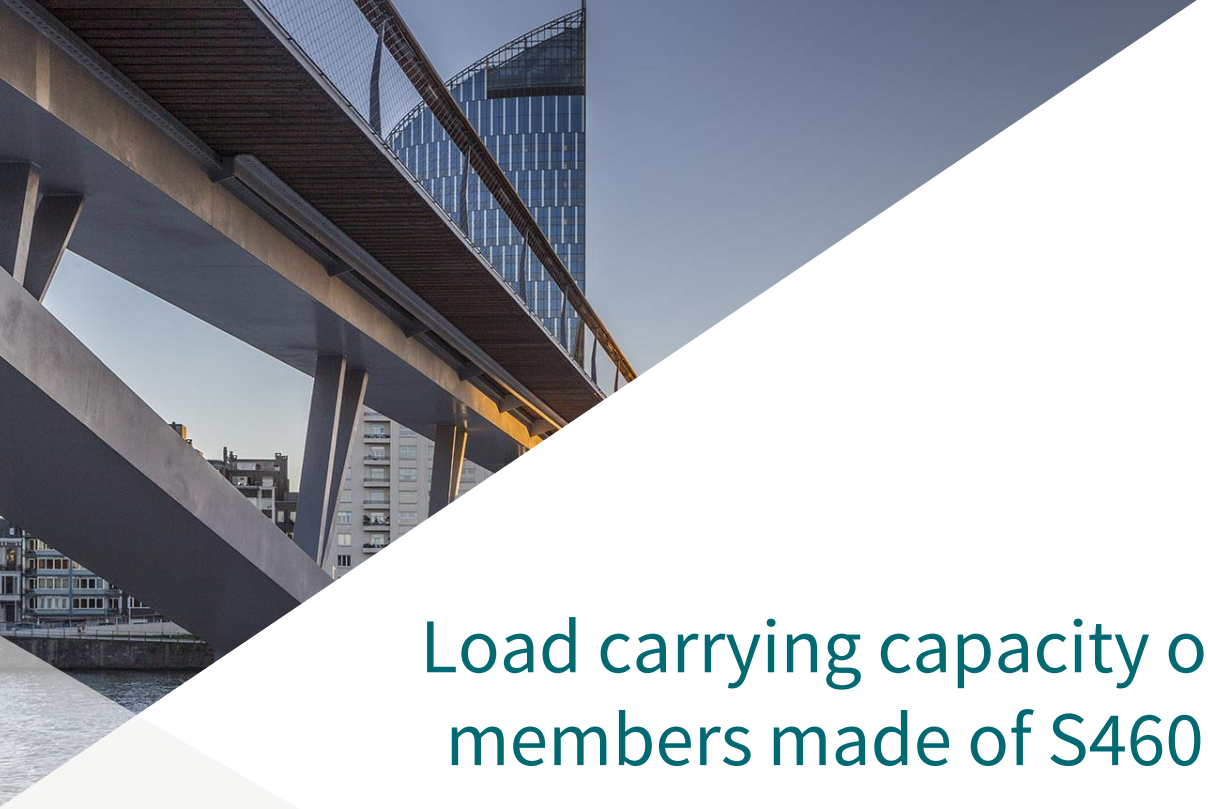

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Load carrying capacity of star-battened angle members made of S460 steel in compression

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State of the art –Scope of the research

- HSS (S460) angles → design and construction of higher and heavier loaded lattice transmission towers.
- Star-battened sections → very high compression loads / strengthening of members.
- Ongoing research project: “New Steel”.

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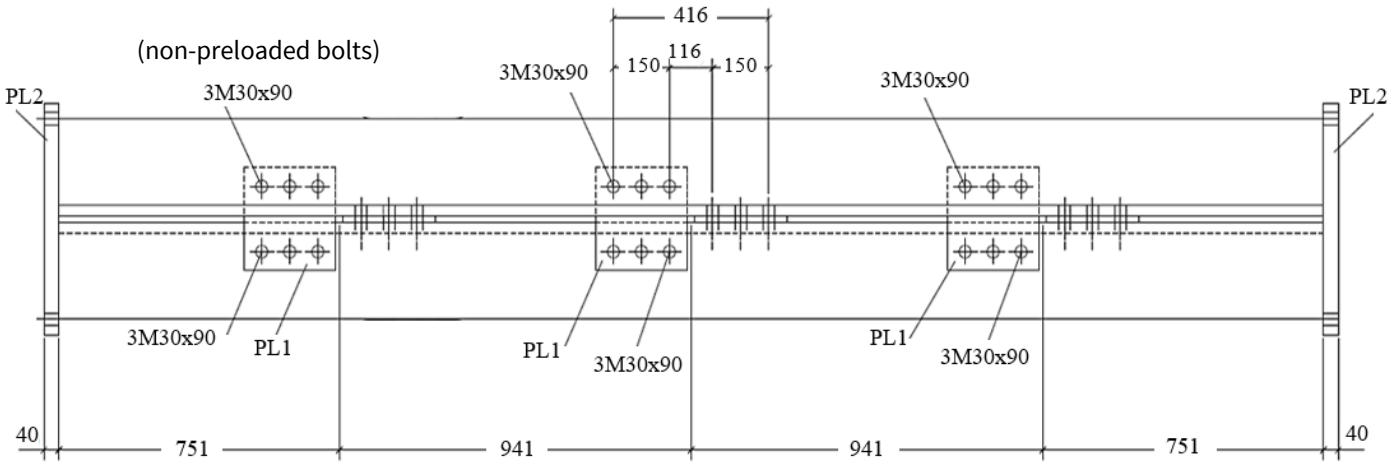
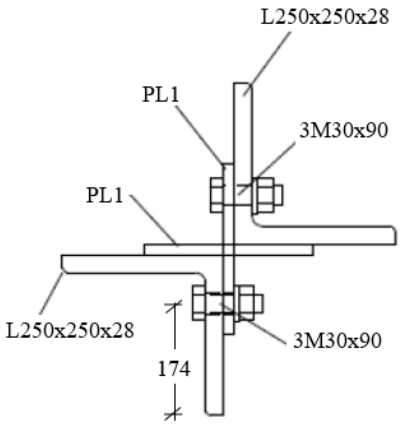
- Objective: determination of the carrying capacity of a SB member made of two S460 L300x300x35 angles with a length of 4486mm that will be used in a specific project of 240m high power transition tower.

- *Bezas et al. (2023) “Buckling resistance of star-battened angle members made of high-strength steel”, Structures, (under review of 1st revision).*

Details of the case study

- Current available design standards (EN 1993-3-1, prEN 1993-3 – Annex F, EN 50341) have been used and compared.
- Studies performed on a star-battened section made of S460 L250x250x28 profiles.
- Its buckling resistance has been evaluated experimentally, analytically and numerically.





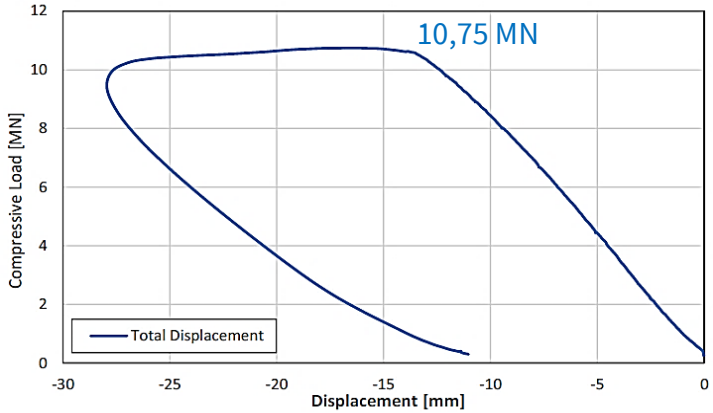
Code review

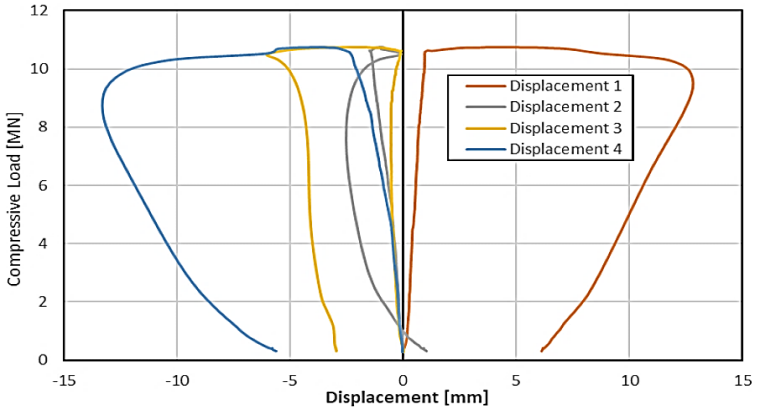
	EN 50341 (Annex J)	EN 1993-3-1	prEN 1993-3
Application for S460	questionable	✓	✓
T/FT modes	✓	✓	**X**
Compound check	✓	**X**	**X** (similar check)
Buckling about u-u axis	a_0	b	b
Buckling about v-v axis	a_0	b	b

- Annex J.4 of EN 50341 can be applied only if full-scale tests are performed, where the experimental resistance should be at least 5% higher than the analytically determined design load for the ultimate limit state.

Experimental test

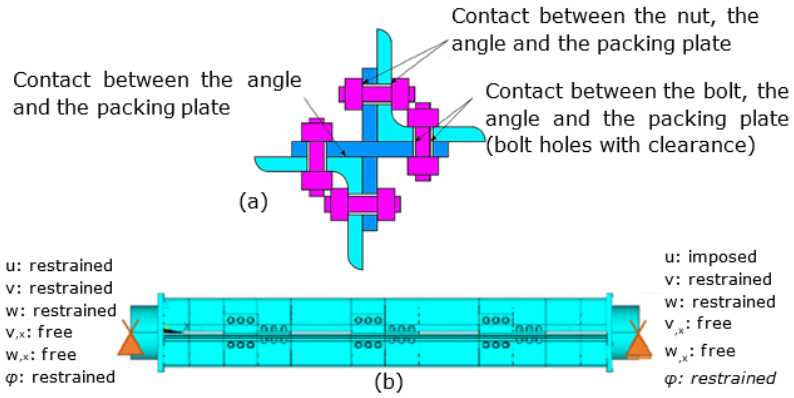
- Initial imperfections, residual stresses and material properties have been measured.
- Displacements (longitudinal/lateral at L/2) + strain gauges at L/4, L/2 & 3L/4.

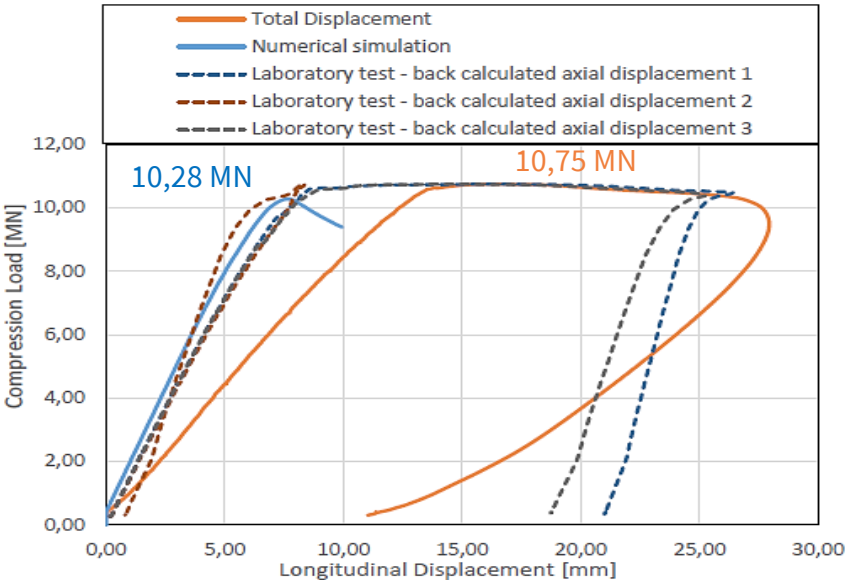




Global (S-shape) and local (at quarter-length) failure mode.

Numerical simulation





- Failure due to global flexural buckling with presence of a local buckling of the legs.
- As the member is rather stocky, flexural buckling is not very significant, while local displacements were low.
- The numerical resistance is about 4% lower than the laboratory one.
- Further numerical studies have shown that a reduction of the thickness of one of the angles constituting the profile has no influence on its failure load, but it may affect the failure mode as local buckling is more pronounced.

Analytical calculations

EN 10025

Measured value

Nominal value

	EN 50341			EN 1993-3-1			prEN 1993-3		
f_y [MPa]	440	445	460	440	445	460	440	445	460
$\overline{\lambda_{eff,F}}$ [-]	0,592	0,592	0,605	0,592	0,592	0,605	0,592	0,592	0,605
$\overline{\lambda_{Sv}}$ [-]	---	---	---	---	---	---	0,524	0,524	0,536
$\overline{\lambda_{eff,T}}$ [-]	0,712	0,711	0,728	0,712	0,711	0,728	---	---	---
$\overline{\lambda_{eff,u}}$ [-]	0,537	0,537	0,550	---	---	---	---	---	---
$\overline{\lambda_{eff}}$ [-]	0,712	0,711	0,728	0,712	0,711	0,728	0,592	0,592	0,605
$N_{b,Rd}$ [MN]	10,44	10,56	10,83	9,09	9,20	9,39	9,84	9,96	10,21
$N_{exp}/N_{b,Rd}$ [-]	1,03	1,02	0,99	1,18	1,17	1,14	1,09	1,08	1,05

Analytical calculations

	EN 50341			EN 1993-3-1			prEN 1993-3		
f_y [MPa]	440	445	460	440	445	460	440	445	460
$\overline{\lambda_{eff,F}}$ [-]	0,592	0,592	0,605	0,592	0,592	0,605	0,592	0,592	0,605
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$\overline{\lambda_{eff}}$ [-]	0,712	0,711	0,728	0,712	0,711	0,728	0,592	0,592	0,605
$N_{b,Rd}$ [MN]	10,44	10,56	10,83	9,09	9,20	9,39	9,84	9,96	10,21
$N_{exp}/N_{b,Rd}$ [-]	1,03	1,02	0,99	1,18	1,17	1,14	1,09	1,08	1,05

- EN 1993-3-1 is the most conservative one, EN 50341 predicts quite well the experimental resistance (even if it has never been validated for S460).
- prEN 1993-3 is always on the safe side but not too conservative, while its background is scientifically and experimentally validated for HSS.
- EN 50341 Annex J.4 cannot be applied as $N_{ult,exp} < 1{,}05N_{b,Rd}$ and so further calculations are required to satisfy this 5% criterion.

Resistance of the SB L300x300x35 S460 member

Normative document	Design resistance $N_{b,Rd}$ [MN]	
	fy = 440 MPa (EN 10025)	fy = 460 MPa
EN 50341	15,66	16,27
EN 1993-3-1	13,79	14,27
prEN 1993-3	14,75	15,31

- Requested capacity: about 15 MN.
- Numerically (GMNIA) determined resistance: 16,62 MN.
- EN 50341 is precise but remains questionable/ EN 1993-3-1 is not conservative/ prEN1993-3 is close and about 7,8 % on the safe side.
- The resistance of the SB L300x300x35 S460 member evaluated with prEN 1993-3 satisfies the requested capacity, even with the use of EN 10025 (as requested in Belgium).

Conclusions

- Different design standards available for the design of SB members in compression → lacks/inconsistencies have been found & their application to S460 members is questionable (EN 50341 will be updated for S460).
- prEN 1993-3:2021 (outcomes of ANGELHY project) proposes a base set of design rules for S460.
- A star-battened member has been considered as a case study and its resistance has been evaluated and compared analytically, experimentally and numerically.
- The ultimate experimental resistance was 10,75 MN. The numerical ultimate resistance equals 10,28 MN, which is about 4% lower than the laboratory test result. In both cases, the failure mode seems to be a combination of global and local buckling.
- An adequate level of resistance of the SB L300x300x35 S460 member with a length of 4486mm for its use in 240 m tower has been reached using prEN 1993-3, even in combination with EN 10025, as the obtained design resistance is of the order of the required one, i.e. about 15 MN

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Thank you for your attendance!

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