

A close-up, high-angle photograph of several stainless steel tubes. The tubes are arranged in a staggered, overlapping pattern, creating a sense of depth and texture. The lighting is dramatic, highlighting the metallic sheen and the sharp edges of the tubes. The background is a soft, out-of-focus white.

# STAINLESS STEEL IS OUR STRENGTH

WEBINAR:

Lean Duplex benefits in bus  
body structures

# STAINLESS STEEL LEAN DUPLEX IN BUS & COACH BUILDING INDUSTRY

1. Presenters
2. Company presentation
3. Stalalube in the bus & coach building industry
4. General info about Duplex and Lean Duplex
5. Mechanical properties of Lean Duplex as a material
6. Mechanical properties of Lean Duplex in tube form
7. Cutting and welding of Lean Duplex
8. Fatigue strength tests
9. Design ideas
10. Questions and discussions

# MEET THE PRESENTERS

## DAVID CORTÉS EXPORT MANAGER

- At Stalatube since 2019
- 8 years of commercial experience in the Transport Industry



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## LARI BRASK DEVELOPMENT MANAGER

- M.Sc (Materials Science)
- International Welding Engineer
- 11 years at Stalatube



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## MARKUS HÄRKÖNEN PRODUCT DEVELOPMENT ENGINEER

- M.Sc. Mechanical engineering
- Mechanical design experience from process industry and from mining equipment industry



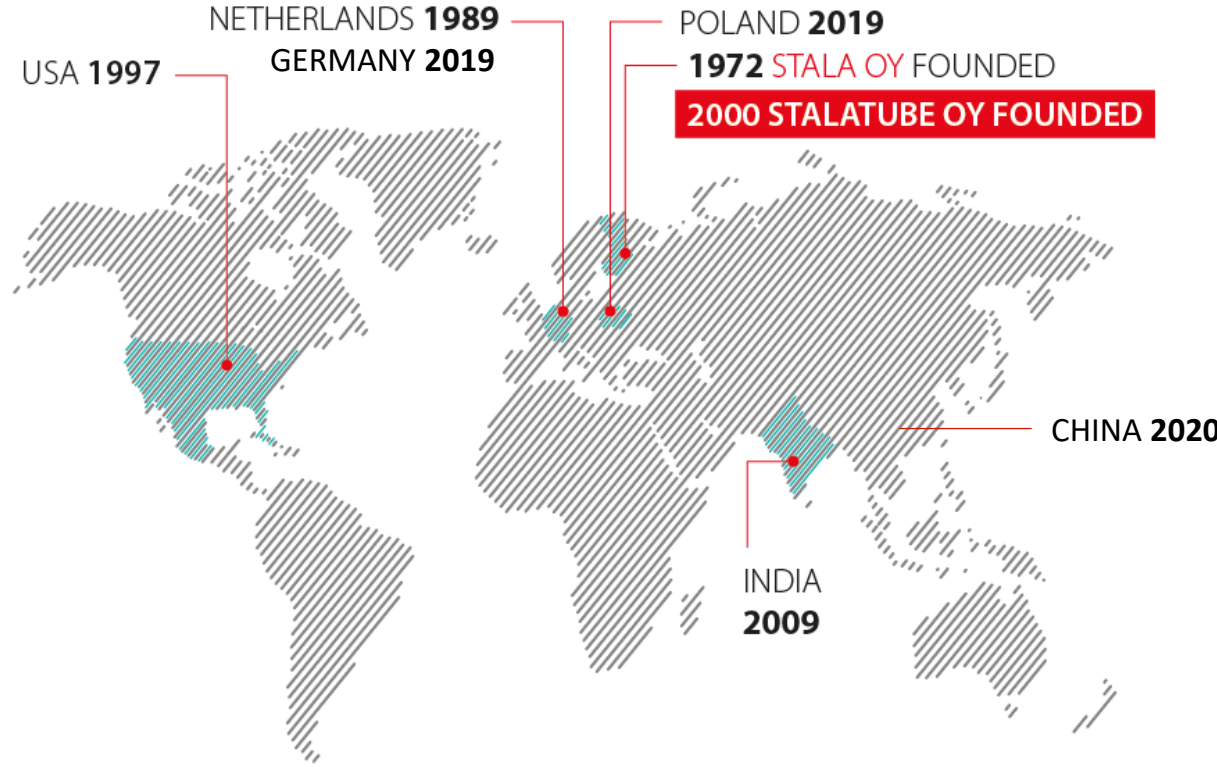
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**STALA**  
TUBE

# STALATUBE IN SHORT



100 %  
STAINLESS STEEL

DELIVERED TONNES  
**28 000<sup>tn</sup>** (2018)

PEOPLE **130**



REVENUE AT  
**100 m€**  
LEVEL

## OUR PRODUCTS



SQUARE & RECTANGULAR  
HOLLOW SECTIONS



STALARGO PRESS BRAKES



I-BEAMS & PROFILES



FLAT BARS



## TRANSPORT

500 Kg off the bus body  
630 Mpa maximum yield strength  
60 % Global market share



## OIL & GAS

40 % Weight savings  
30 Years experience  
50-Year life cycle  
M-650 norsok approved



## OTHER INDUSTRIES

- Good corrosion & heat resistance
- Hygienicity, durability, strength & ductility
- Maintenance-free & low life cycle costs
- Aesthetic appearance

## SUSTAINABILITY



CLOSED-LOOP  
WATER SYSTEM  
in production

2/3

RECYCLED  
raw materials



100%  
RECYCLABLE  
products

## CERTIFICATES

ISO 9001

ISO 14001

ISO 3834-2

OHSAS 18001

EN 10088-5

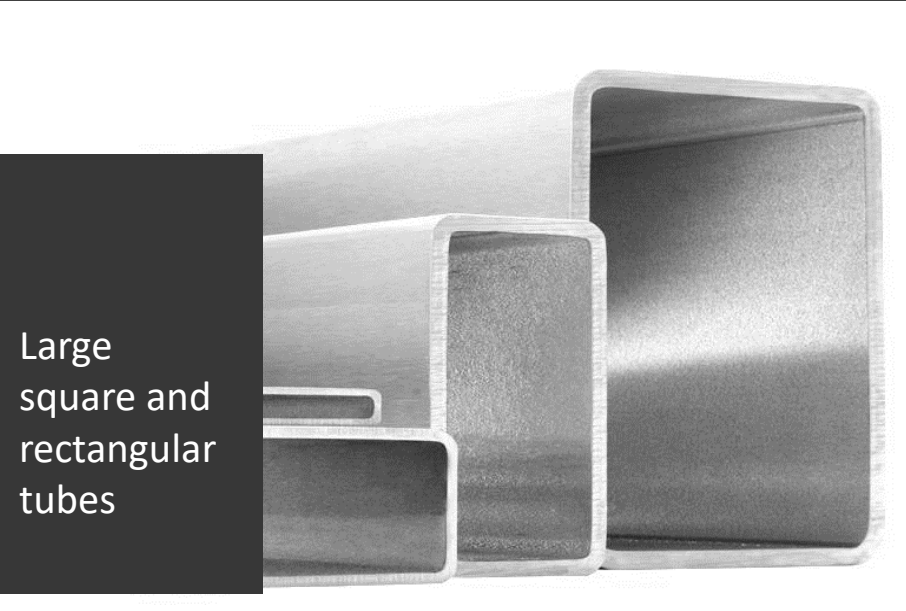
EN 1090-1

1/3 of headquarters' energy needs covered with  
**SOLAR PANELS**



**STALA**  
TUBE

# OUR MAIN PRODUCTS

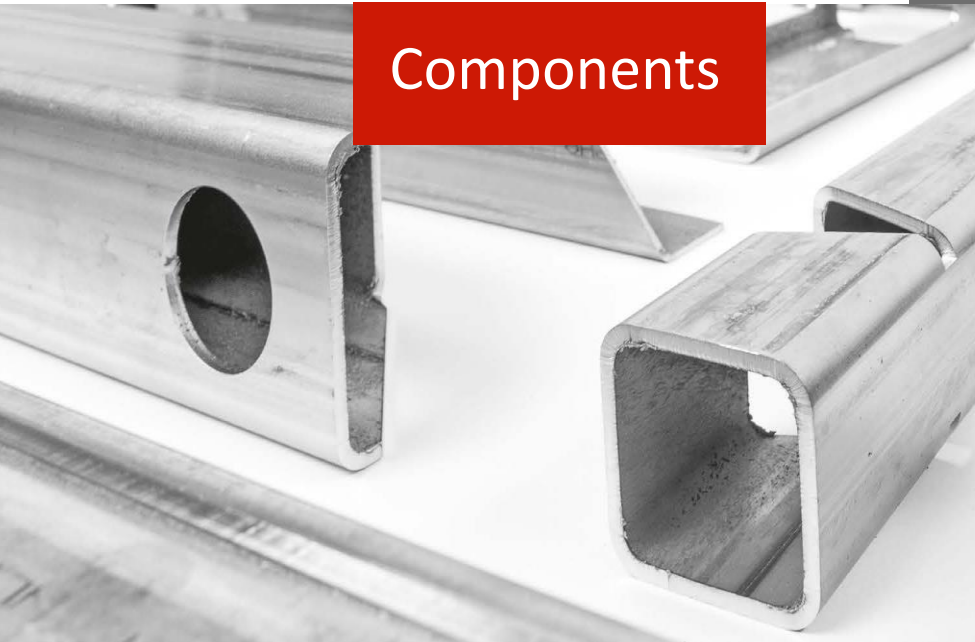


Large square and rectangular tubes

Duplex and lean duplex tubes



Ferritic tubes



Components

Tailored products



I-beams

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# REFERENCES FROM THE TRANSPORT INDUSTRY



# STAINLESS STEEL IN THE BUS BUILDING INDUSTRY

- Stainless steel has been used decades in bus building industry
- Still only about 3%-5% of all buses are made of stainless steel
- Nowadays it is mainly ferritic EN 1.4003 stainless steel. In the US coach builders are also using 304 austenitic stainless steel
- Due to weight savings high strength Lean Duplex stainless steel is getting more and more popular

# ADVANTAGES OF STAINLESS STEEL



Maintenance Free



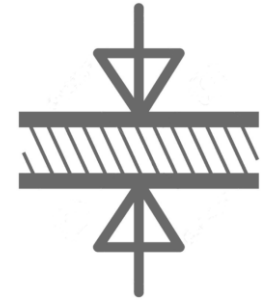
100% Recyclable



x250 Better  
Corrosion Resistance



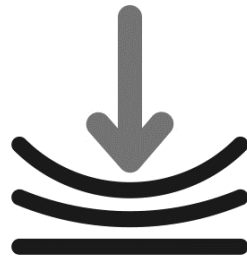
High Strength  
=  
Weight Reduction



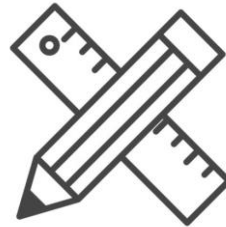
Less Material  
=  
Weight Reduction



Lower LCC



70-90%  
Better Energy Absorption



Custom Made  
High Versatility



Superior Elongation



Longer lasting  
attractive finish  
without treatments

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# MATERIALS USED IN TRANSPORT INDUSTRY

## AUSTENITIC

EN 1.4301 (AISI 304)

### STALA 350

Min. yield strength 350MPa

Min. tensile strength 600MPa

Min. elongation 30%

Standard yield strength 220MPa

## FERRITIC

EN 1.4003 (S40977)

### STALA 400F

Min. yield strength 400MPa

Min. tensile strength 450MPa

Min. elongation 10%

Standard yield strength 320MPa

## LEAN DUPLEX

EN 1.4162 (DX 2202) /

EN 1.4062 (LDX 2101)

### STALA 630D

Min. yield strength 630MPa

Min. tensile strength 750MPa

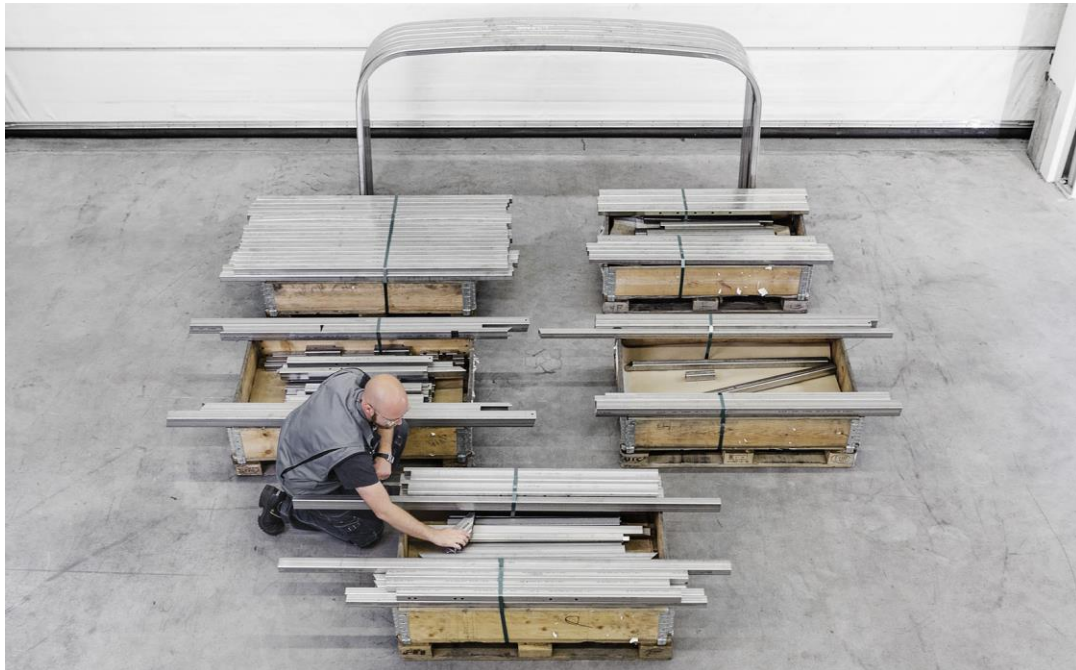
Min. elongation 20%

Standard yield strength 500MPa

YIELD  
STRENGTH  
UP TO  
**630 MPa**

# COMPONENTS CASE SCANIA

- Industry: Transport
- Application: Bus body structure
- Tailored solutions, laser cut, ready-made and packed components for final assembly
- Duplex and Ferritic Stainless Steel
- Destination: Finland and Poland



# LIFE CYCLE COSTS EXAMPLE

Cost	Duplex 1.4062 + Ferritic 1.4003 1350 kg/body	Ferritic 1.4003 1500 kg/body	Carbon steel 1500 kg/body
Materials	\$ 3 818	\$ 3 375	\$ 1 680
Repairs (20 years)	\$ 0	\$ 0	\$ 4 500
Fuel saving (citybus) per 1M km	- \$ 6 065	± \$ 0	± \$ 0
<b>Total life cycle costs (20 years)</b>	<b>- \$ 2 247</b>	<b>+ \$ 3 375</b>	<b>+ \$ 6 180</b>

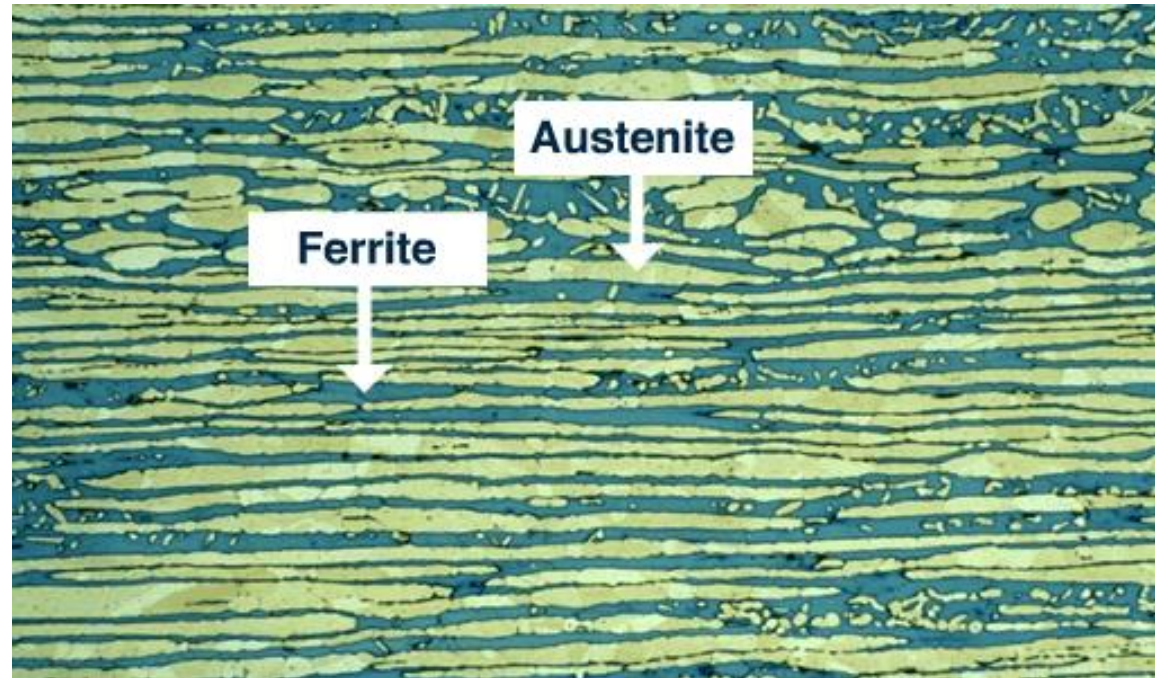
Note also higher passenger capacity and lower CO2 emissions  
(20 tons with DX+Fe in 1Mkm)



# STAINLESS STEEL LEAN DUPLEX IN BUS & COACH BUILDING INDUSTRY

# WHAT IS DUPLEX?

Duplex stainless steel is a mixture of austenite and ferrite. So it is like a composite material.



[www.imoa.info](http://www.imoa.info)

Ferrite is hard and austenite is tough. That makes a good combination.

# HISTORY OF DUPLEX

Duplex stainless steels has been used almost hundred years. In the beginning they were used mainly in castings. (Weldability of those duplex grades was bad.)

The reason for this was to avoid hot cracking in castings. (austenitics are prone to that.)

Using of duplex in other products than castings became more common in 1970s when steel refining process had improved enough, and first commonly recognized duplex grade was established. That grade was duplex 2205 / EN 1.4462. It is still the most common duplex grade in the world.

Duplex grades were mainly used in oil&gas industry.

That 2205 is kind of "standard" duplex grade. After that more corrosion resistant duplex grades called super duplex grades has been developed.

Newest group of duplex grades is group of lean duplex grades. Lean duplex grades were developed to replace common austenitic grades like 304 and 316. The reason for this was high nickel price.

# MODERN LEAN DUPLEX GRADES

- Modern lean duplex grades were developed to replace common austenitic grades.
- The problem with common austenitic grades is high nickel (8 – 11 %) content which causes price to fluctuate.
- Lean duplex grades typically have 1.5 – 4 % of nickel which gives much better price stability.
- Duplex microstructure also provides much higher strength compared to austenitic or ferritic grades.

Here is typical chemical composition and mechanical properties of two common lean duplex grades and two other grades for comparison:

EN -number	Cr %	Ni %	Mo %	N %	Rp0.2 [MPa]*	Rm [MPa]*	PREN
1.4162	21.5	1.5	0.3	0.22	480	680	26
1.4062	23.0	2.5	0.15	0.20	480	680	26
1.4301	18.1	8.1	-	-	230	520	18
1.4003	11.5	0.5	-	-	320	450	11

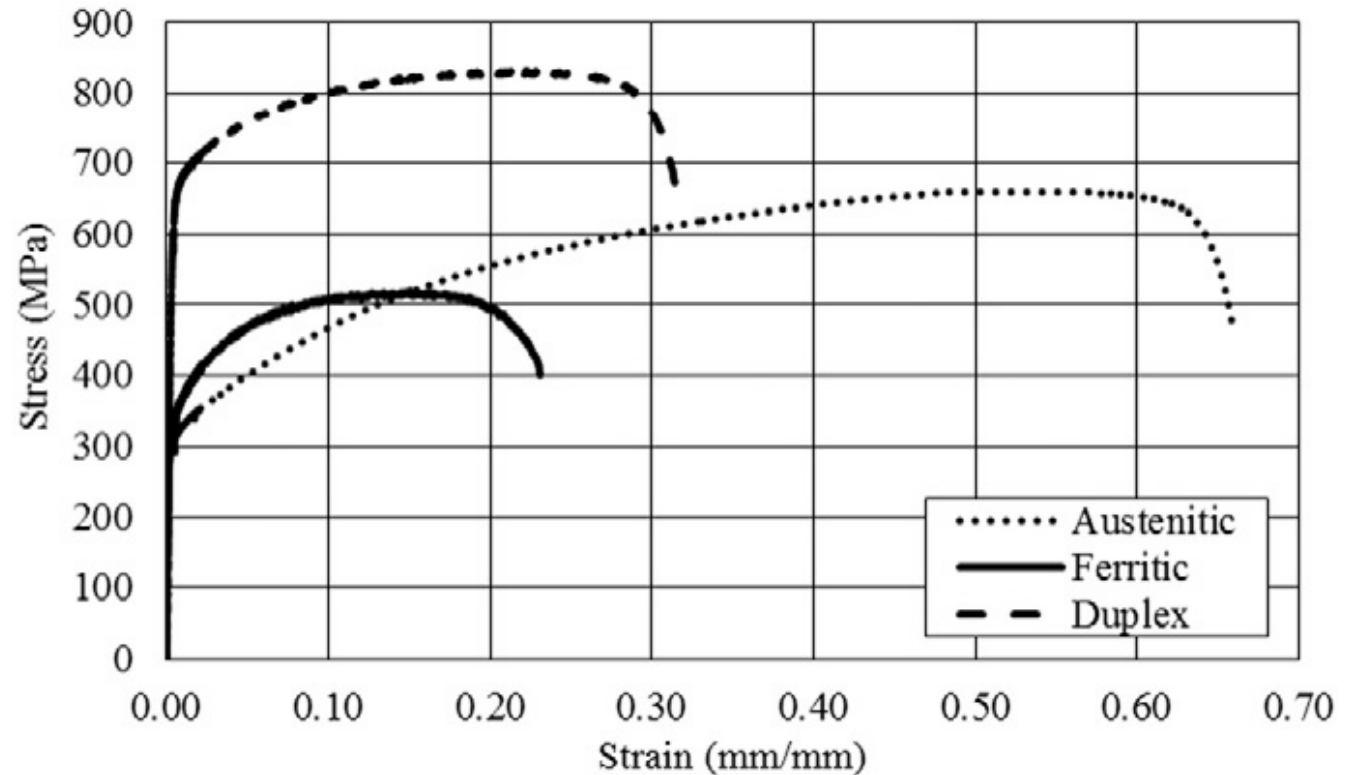
\* Minimum values for a coil

$$\text{PREN} = \text{Cr}\% + 3.3 \times \text{Mo}\% + 16 \times \text{N}\%$$

# MECHANICAL PROPERTIES OF LEAN DUPLEX

Lean duplex grades have much higher strength compared to austenitic or ferritic grades. Stress-strain curve of S355 is very similar to ferritic stainless steel. High strength and good elongation of lean duplex provides excellent energy absorption capacity.

Stalatube can offer lean duplex (EN 1.4062 / 1.4162) hollow sections with **yield strength of 630 MPa** and minimum elongation of 20% (Stala 630D).



*I. Arrayago et al. / Materials and Design 87 (2015) 540–552*



# LEAN DUPLEX HOLLOW SECTIONS

- Lean duplex hollow sections offers possibility to reduce weight compared ferritic and austenitic stainless steel grades.
- Lean duplex hollow sections have also much better corrosion resistance compared to EN 1.4003.
- High strength and good elongation makes lean duplex an ideal material for roll-over structures in a bus body.
- Weldability of these modern lean duplex grades is also very good.

Here is Stalalube's product range of lean duplex hollows sections for transportation industry:

- 25x25x1.5 mm – 100x100x4 mm.
- Most of those dimensions are also available in strength class Stala 630D ( $R_{p0.2} \geq 630$  MPa).
- Custom sizes are also possible.

The logo for Stalalube Tube, featuring the word "STALA" in a bold, red, sans-serif font above the word "TUBE" in a smaller, grey, sans-serif font.

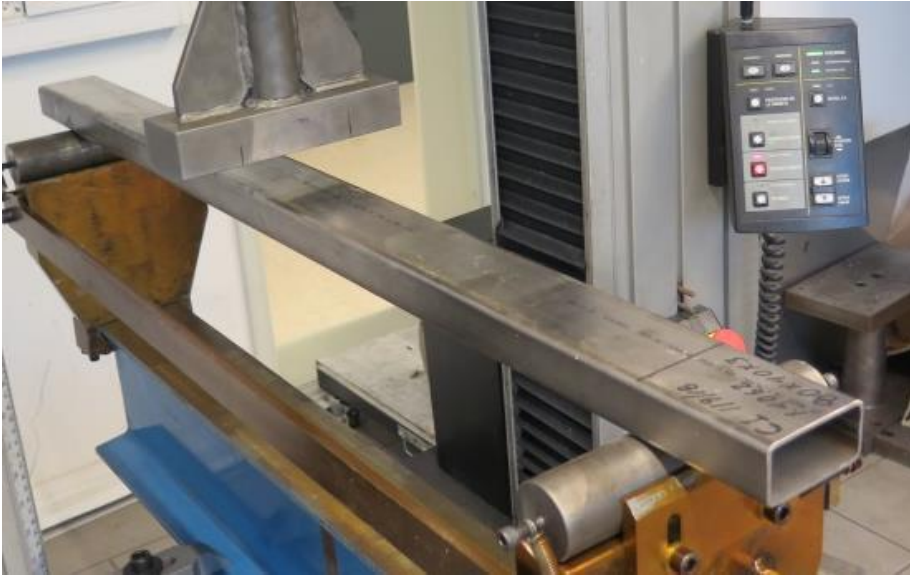
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# TENSILE TEST RESULTS

Note: True values

Profile	Sample	Thickness (mm)	Yield Strength (MPa) <sup>(a)</sup>	Ultimate Strength (MPa) <sup>(a)</sup>	Homogeneous Elongation (%) <sup>(a)</sup>	Elongation at break (%) <sup>(b)</sup>
80x40x3	A-01	3	702	908	21.47%	27.26%
	A-02	3	686	903	20.82%	26.70%
	A-03	3	708	898	19.19%	24.91%
60x60x3	B-01	3	745	932	16.25%	22.15%
	B-02	3	744	935	16.40%	22.11%
	B-03	3	747	931	15.30%	21.27%
70x50x3	C-01	3	687	921	22.52%	28.18%
	C-02	3	697	924	22.41%	28.21%
	C-03	3	686	922	22.52%	28.41%
100x40x2	D-01	2	687	959	23.22%	27.74%
	D-02	2	700	949	20.58%	25.39%
	D-03	2	671	949	22.89%	27.48%

# BENDING RESISTANCE



Single profile bending test



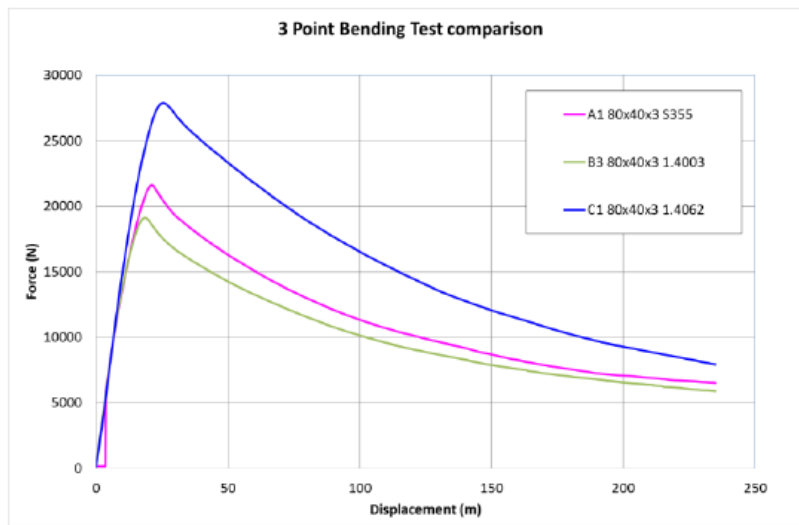
Double profile bending test

# BENDING RESISTANCE

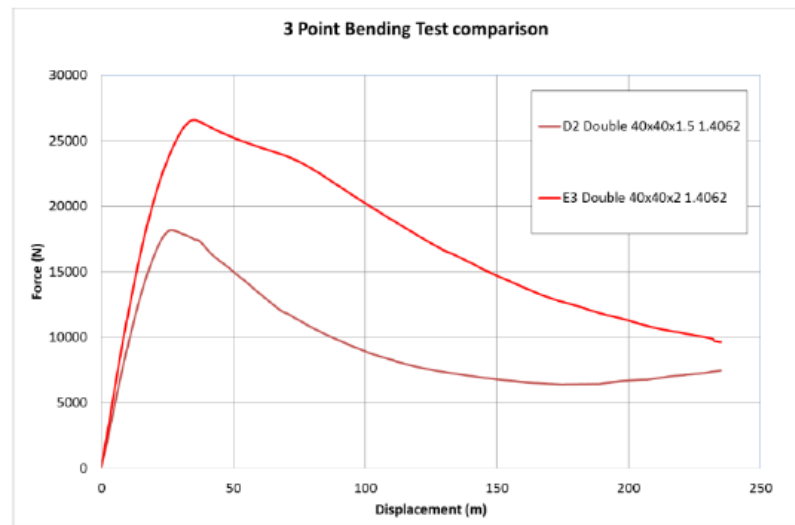
- Comparison of the best profiles for each test:

Profile	Material	Sample code	IDIADA Reference	Span [mm]	$F_{max}[Kg]$	$M_{max}[Nm]$	Roll-bar angle $_{max.}$ ( $^{\circ}$ )
80x40x3	S355	A1	DE18030086	1000	2203	5403	50 $^{\circ}$
80x40x3	1.4003	B3		1000	1950	4782	50 $^{\circ}$
80x40x3	1.4062	C1		1000	2843	6973	50 $^{\circ}$
2x 40x40x1.5	1.4062	D2		1000	1852	4543	50 $^{\circ}$
2x 40x40x2	1.4062	E3		1000	2708	6642	50 $^{\circ}$

- Graphical comparison of the best profiles for each test divided in single or double profiles:



single profiles



double profiles

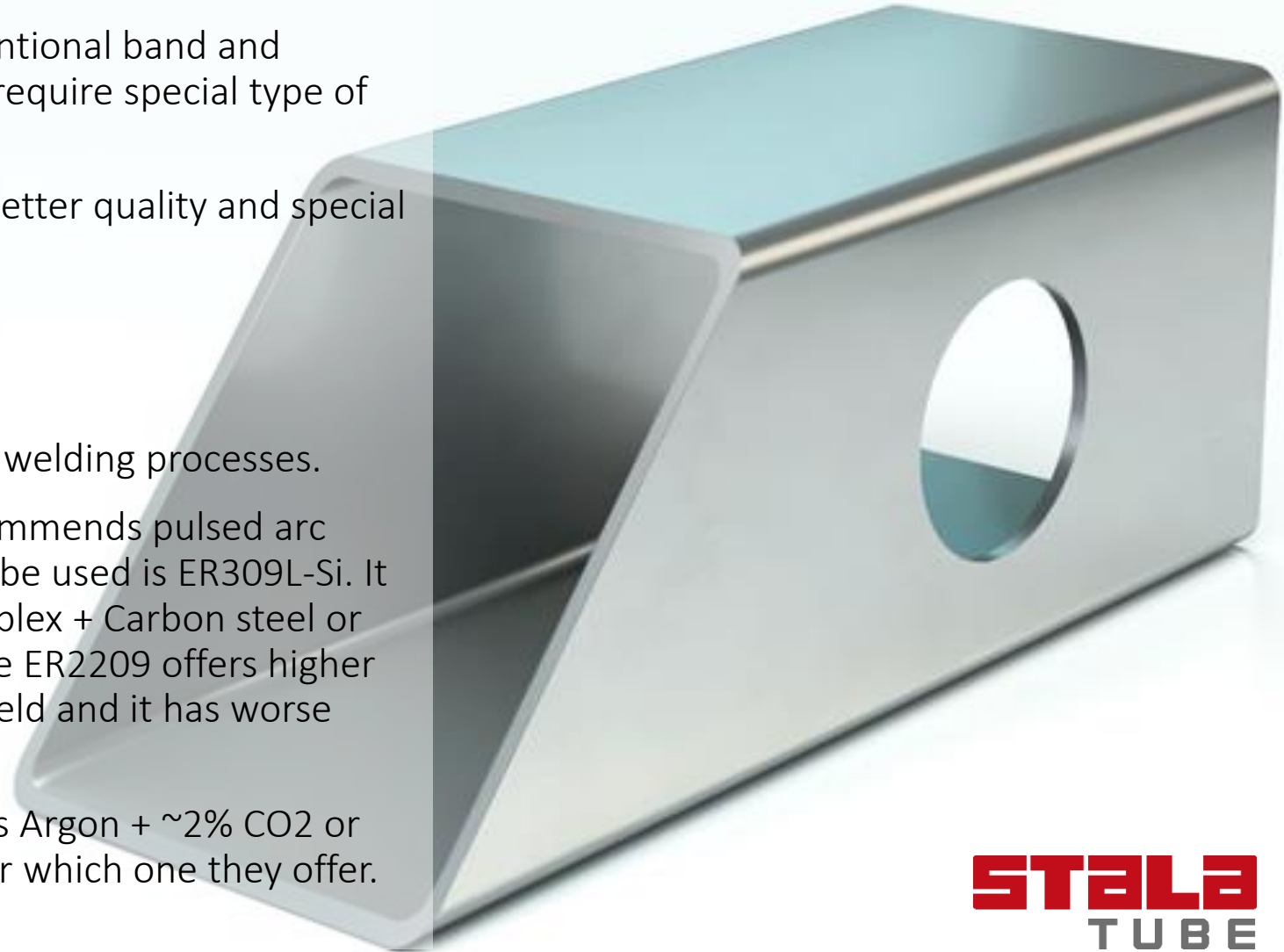
# CUTTING AND WELDING

## Cutting of lean duplex:

- Lean duplex hollow sections can be cut by conventional band and circular saws. High strength of the material may require special type of saw blade.
- Stalalube recommends laser cutting to achieve better quality and special shapes.

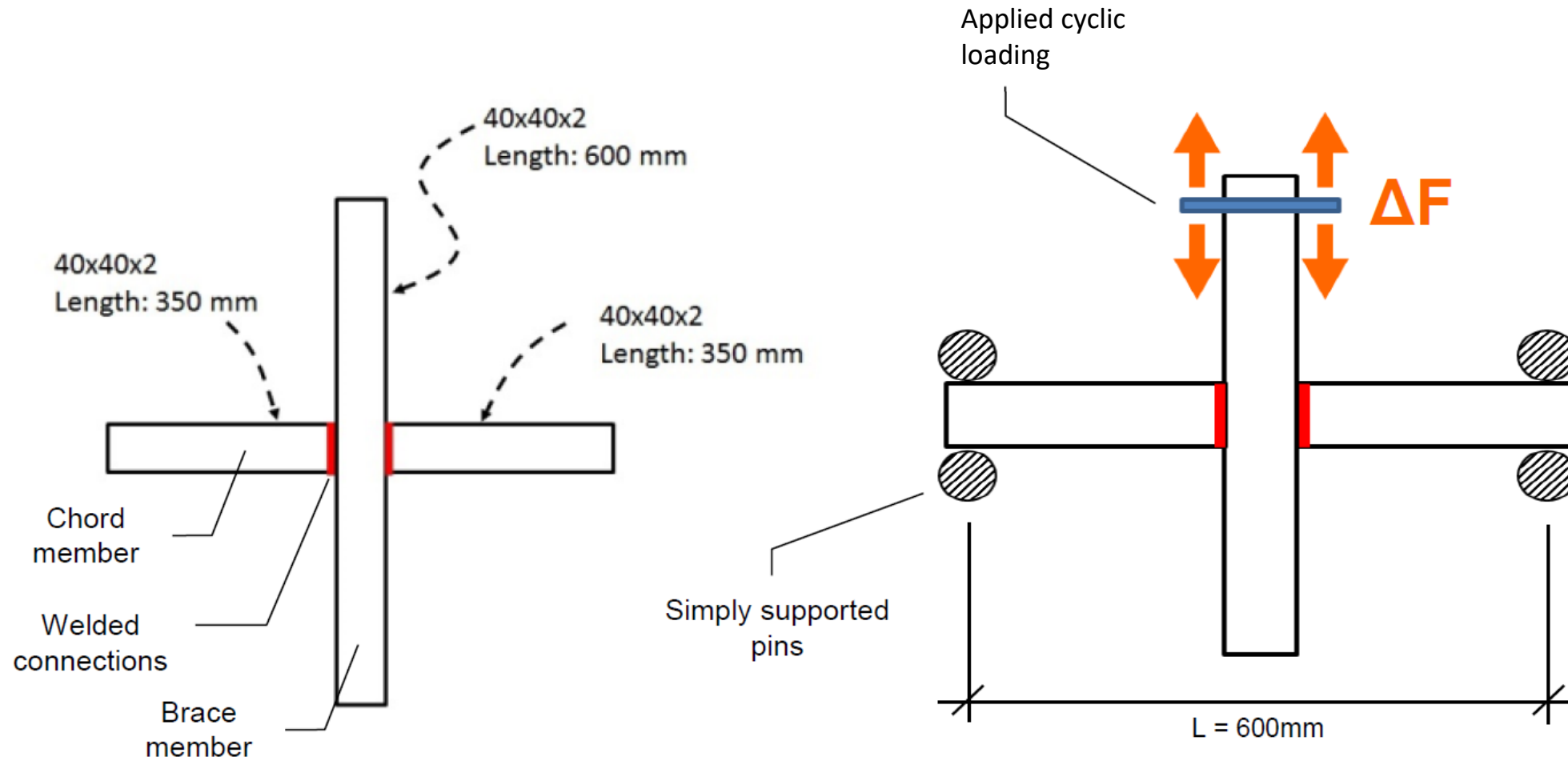
## Welding of lean duplex:

- Lean duplex can be welded with all conventional welding processes.
- For bus and coach manufacturing Stalalube recommends pulsed arc MAG –welding. Common welding wire what can be used is ER309L-Si. It can be used for dissimilar welds as well (Lean duplex + Carbon steel or Lean duplex + Ferritic stainless steel). Duplex wire ER2209 offers higher strength than 309L-Si but it is more difficult to weld and it has worse availability.
- Recommended shielding gas for MAG –welding is Argon + ~2% CO<sub>2</sub> or O<sub>2</sub>. Please consult your local welding gas supplier which one they offer.



# FATIGUE TESTS WITH LDX

# TEST SET-UP



Schematic view of the cross-joint (left) and of the experiment (right), designed and performed with the aim of evaluating the fatigue performance of the joint configuration.

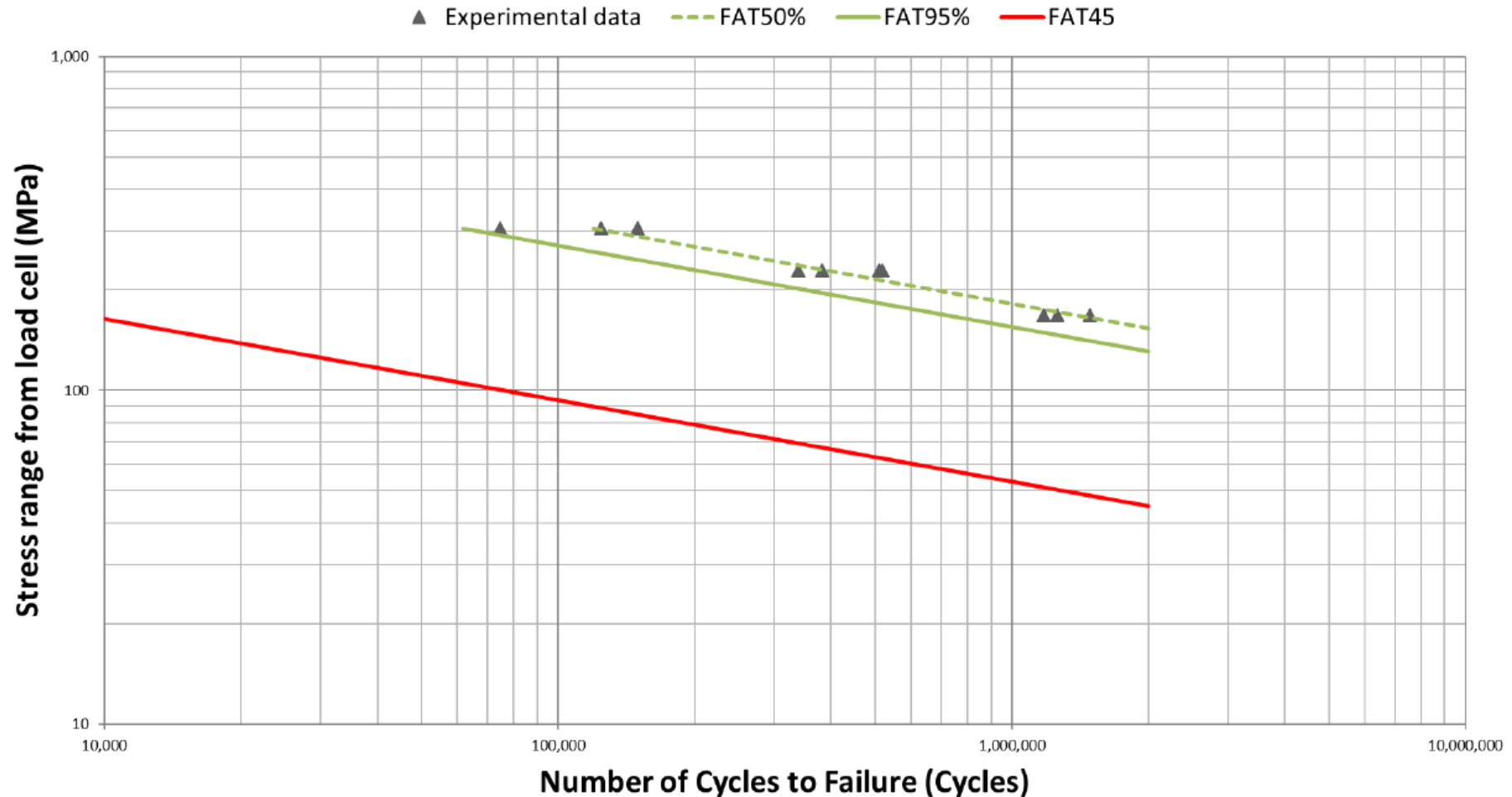
# RESULTS



Different views of tested samples after fatigue failure takes place. Note that crack initiation is located at weld seams' toes (stress concentration areas) and grow longitudinally towards the opposite corners. All the specimens showed the same damage pattern.



# RESULTS

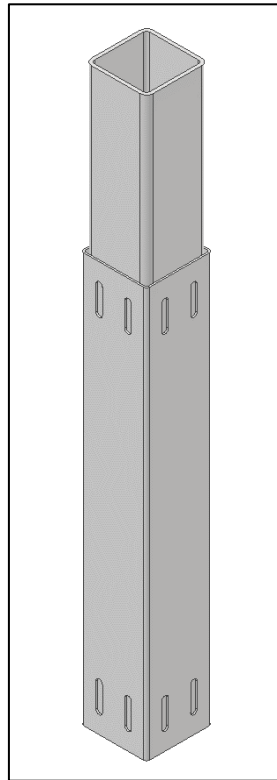
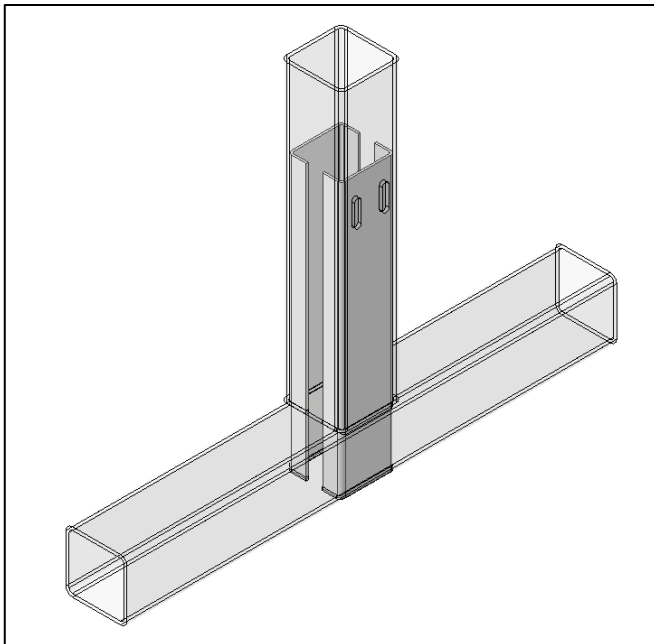


Fatigue test results: average (FAT50%), characteristics (FAT95%) S-N curves of EN 1.4062 steel cross-joint from the samples, using a nominal stress approach. A slope  $m \sim 4.10$  has been obtained. Fatigue class 45 (FAT45) curve has been added for comparison purposes.

# DESIGN DIFFERENCES

## Reinforced joints

Helps to increase fatigue resistance without increasing the size of the joint

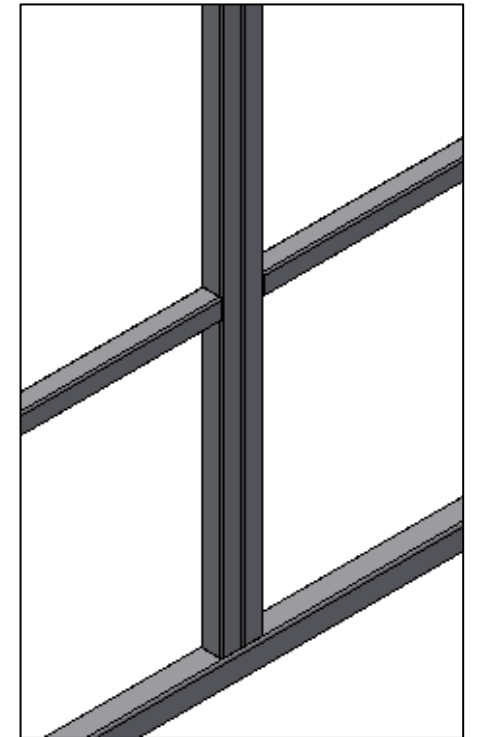


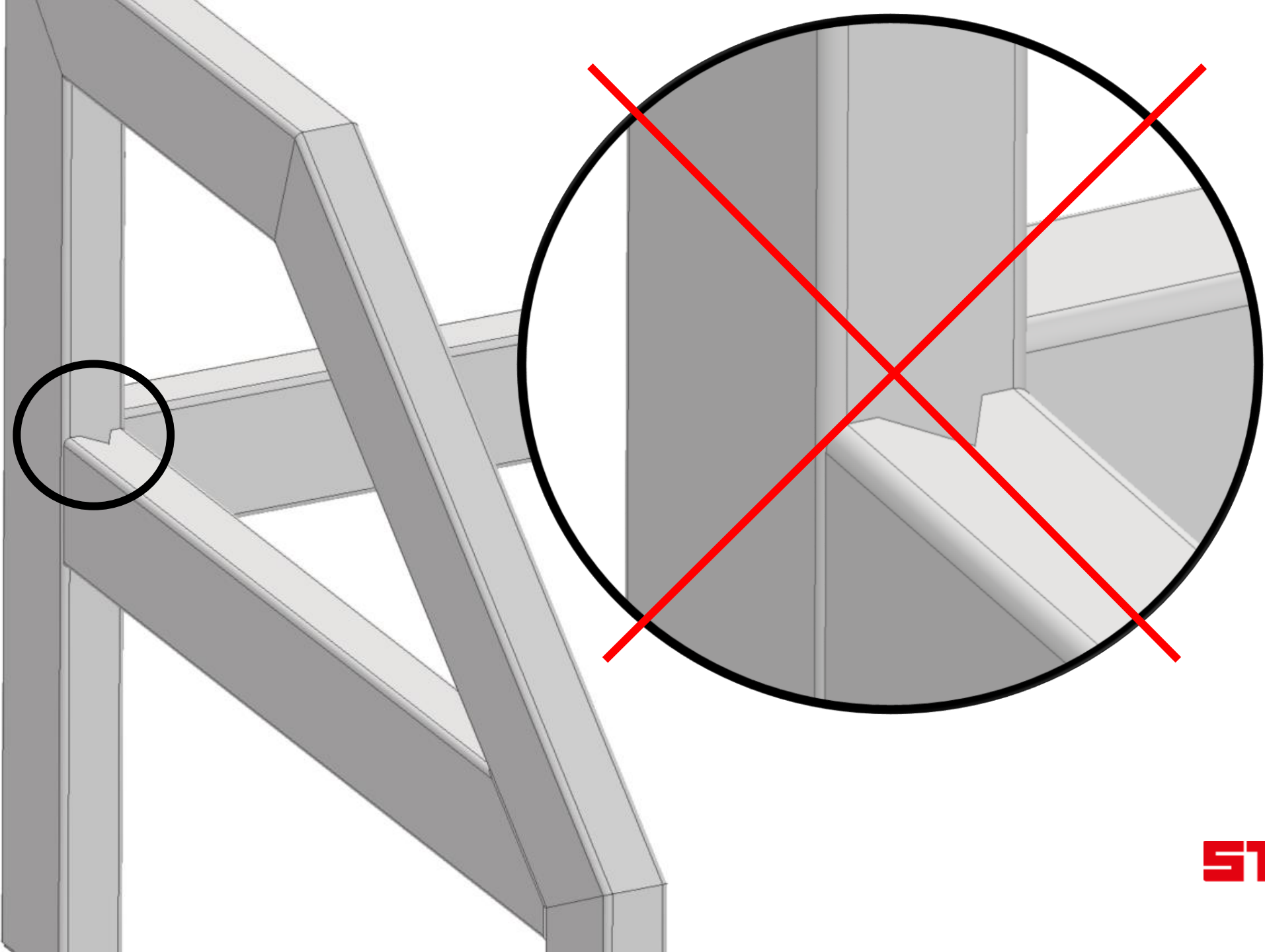
## Tube in a tube

In cases where the largest wall thickness of certain tube isn't enough, the moment of inertia can be increased with placing another tube inside the outer tube.

## Tube by tube

Even though the moment of inertia would be the same with a single tube, tube by tube construction increases the buckling resistance and performs better at plastic deformation situations.





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# YOUR BIGGEST CONCERNS BEFORE THE WEBINAR



COST SAVINGS

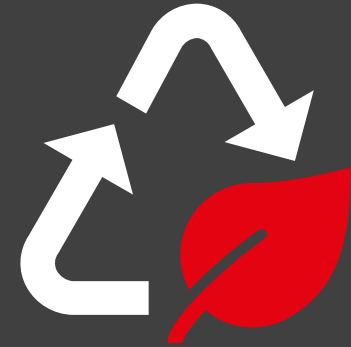


**OFF?**

WEIGHT SAVINGS



UPWARD TREND



ECO-FRIENDLY

Any more questions?

THANK YOU!

USE **OUR**  
STRENGTH

[www.stalatube.com](http://www.stalatube.com)