

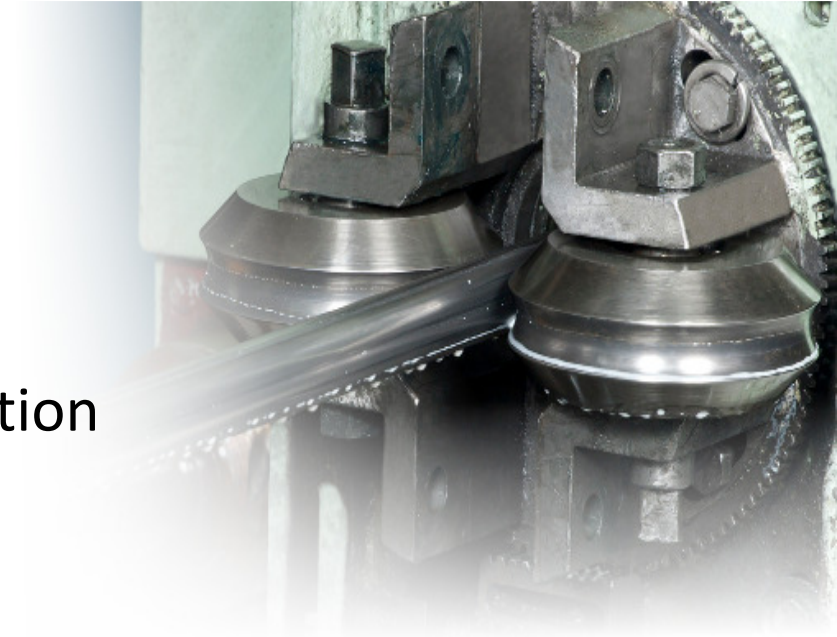
# SSAB

Danish Steel Building Day

Jan Österholm

# Contents

- ▶ SSAB:s tube offer short on tube production
- ▶ SSAB:s hollow sections and steel grades
- ▶ Cold formed versus Hot formed
- ▶ CorTen hollow sections



# Tubes & Sections

## Production

- ▶ 7 Production units
- ▶ Total 14 tube lines, 8 open section lines
- ▶ Total capacity of 400.000 tons annually



# General Tubes & Sections

Focus on High Strength Steels

## Structural Hollow Sections

- Cold formed and welded
- Spirally welded
- Variation of grades and dimensions



## Precision Tubes

- Cold formed and welded
- Close tolerances
- Variation of grades and dimensions



## Cold Roll Formed Sections

- Roll formed
- Steel and shape for optimal solution



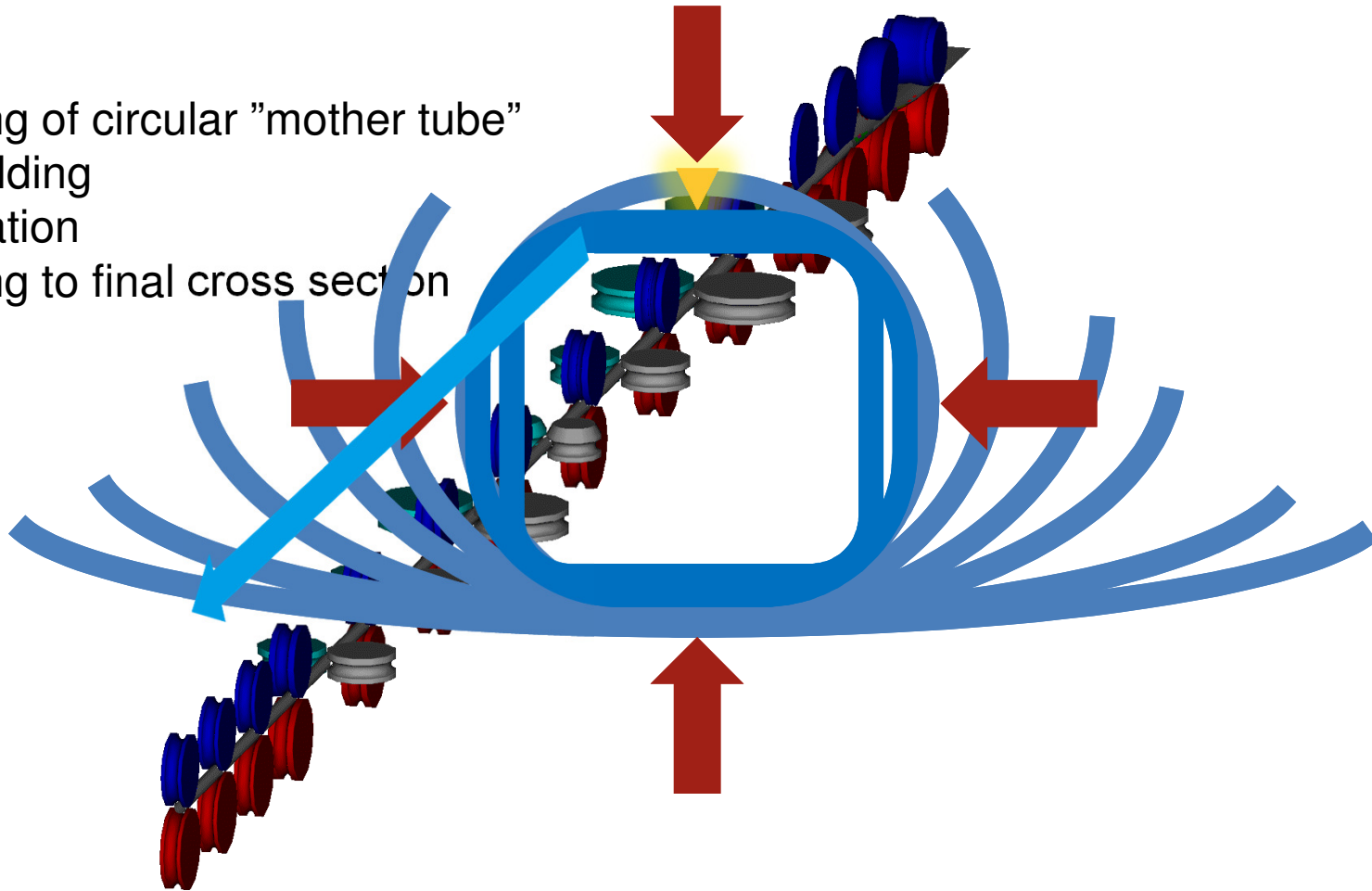
## Line Pipes & Pressure Tubes

- Welded hot formed and normalized
- Variation of grades and surface conditions



# Tube cold forming process

- 1 Forming of circular "mother tube"
- 2 HF-welding
- 3 Calibration
- 4 Forming to final cross section





# Hollow sections

HFSHS EN 10210  
hot formed

CFSHS EN 10219  
cold formed

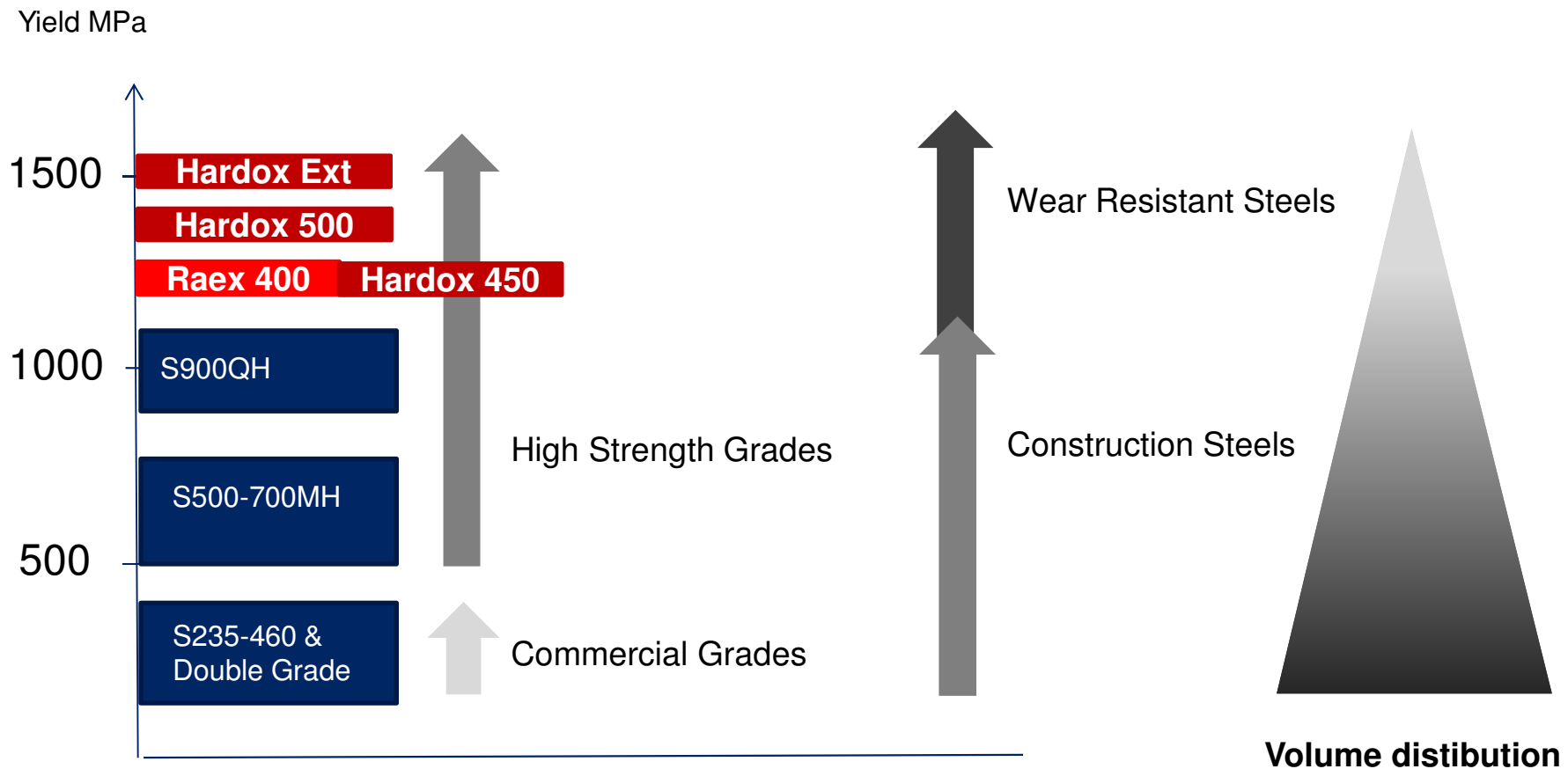
SSAB manufactures cold formed hollow sections

Approx. 100.000 ton/year

All SSAB hollow sections are CE-marked



# Hollow Sections in Different Steel Grades



# Standard steel grade

## Double grade

- Double grade fullfills the specifications in EN 10219 both for S355J2H and S420 MH
- Double grade has a guaranteed yield strength of 420 MPa
- Double grade is delivered with two separate certificates, S355J2H and S420 MH
- Double grade allows for weight reductions up to 15% or alternatively to allow for new solutions, longer spans f.ex.





# Cold formed vs Hot formed



**Cold formed**

**EN 10219**

**Produced in  
room temperature**



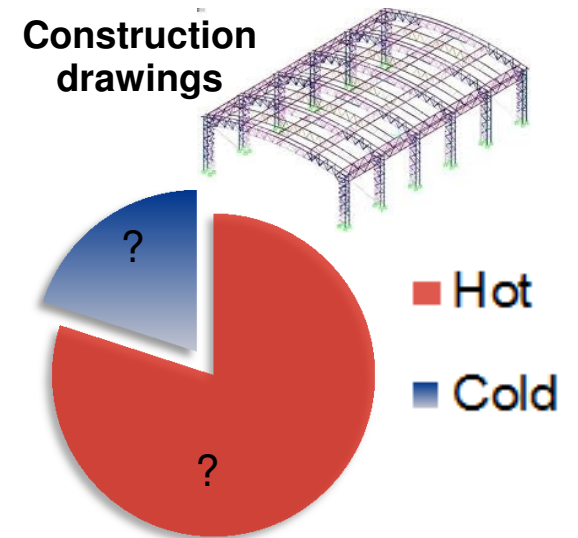
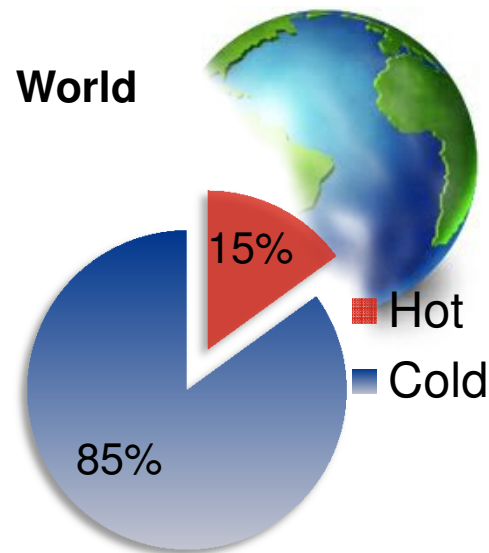
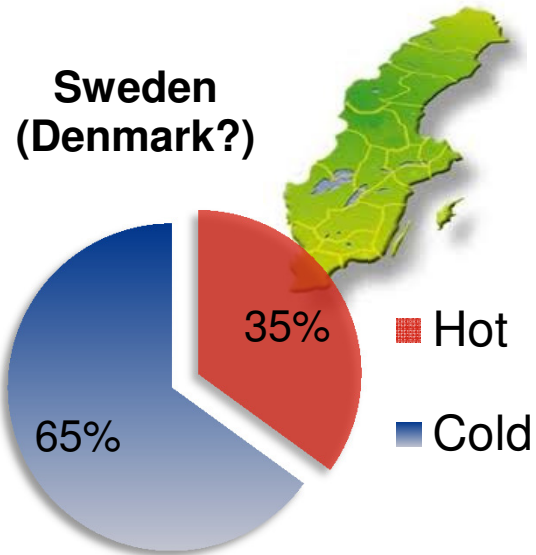
**Hot formed**

**EN 10210**

**Produced at  
700 - 1000°C**



## Market use of hot formed and cold formed





## Price extra for hot formed vs cold formed

Dimension	Swedish distributor 2013
200 x 200 x 10 VKR/KKR	+20%
200 x 200 x 12,5 VKR/KKR	+23%
150 x 150 x 6,3 VKR/KKR	+24%
150 x 150 x 8 VKR/KKR	+26%



What are the reasons that hot formed hollow sections are to high extent specified in construction design drawings?

- ▶ Tradition ?
- ▶ Lack of information on cold formed?
- ▶ There are also claims on the market that cold formed hollow sections are not safe and reliable products. These claims refer to that the production method gives products with inferior properties



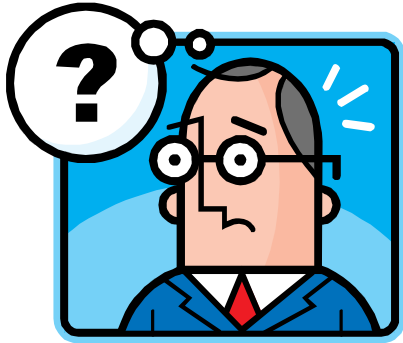


# Standards

- Both products are generally accepted and treated equally in relevant parts of Eurocode 3
- Both product are treated equally in EN 1090







# Cold formed hollow sections

## suitability for steel construction

– common claims

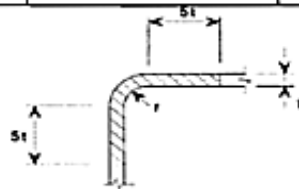
- ▶ **Not allowed to weld in corners**
- ▶ Insufficient deformation capacities in welded joints
- ▶ Insufficient buckling resistance compared to hot formed
- ▶ Insufficient fatigue strength
- ▶ Insufficient ductility in low temperatures
- ▶ Insufficient and unpredictable strength in fire
- ▶ Too round corners compared to hot formed
- ▶ Not suitable for hot dip galvanising

# Welding in corners of cold formed hollow sections



**Table 4.2: Conditions for welding cold-formed zones and adjacent material**

r/t	Strain due to cold forming (%)	Maximum thickness (mm)		
		Generally		Fully killed Aluminium-killed steel (Al ≥ 0,02 %)
		Predominantly static loading	Where fatigue predominates	
IV 25	≤ 2	any	any	any
IV 10	≤ 5	any	16	any
IV 3,0	≤ 14	24	12	24
IV 2,0	≤ 20	12	10	12
IV 1,5	≤ 25	8	8	10
IV 1,0	≤ 33	4	4	6



**NOTE** Cold formed hollow sections according to EN 10.219 which do not satisfy the limits given in Table 4.2 can be assumed to satisfy these limits if these sections have a thickness not exceeding 12,5 mm and are Al-killed with a quality J2H, K2H, MH, MLH, NH or NLH and further satisfy  $C \leq 0,18\%$ ,  $P \leq 0,020\%$  and  $S \leq 0,012\%$ .

In other cases welding is only permitted within a distance of  $5t$  from the corners if it can be shown by tests that welding is permitted for that particular application.

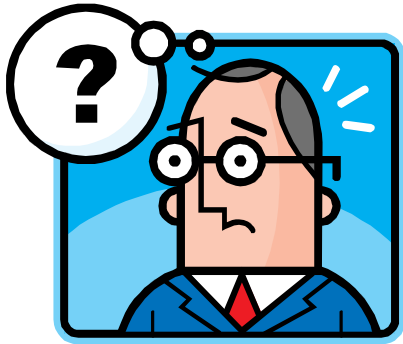


## Welding in corners of cold formed hollow sections



AC2 NOTE Cold formed hollow sections according to EN 10219 which do not satisfy the limits given in Table 4.2 can be assumed to satisfy these limits if these sections have a thickness not exceeding 12,5 mm and are Al-killed with a quality J2H, K2H, MH, MLH, NH or NLH and further satisfy  $C \leq 0,18\%$ ,  $P \leq 0,020\%$ , and  $S \leq 0,012\%$ .

SSAB:s hollow sections have satisfied this requirement for over a decade



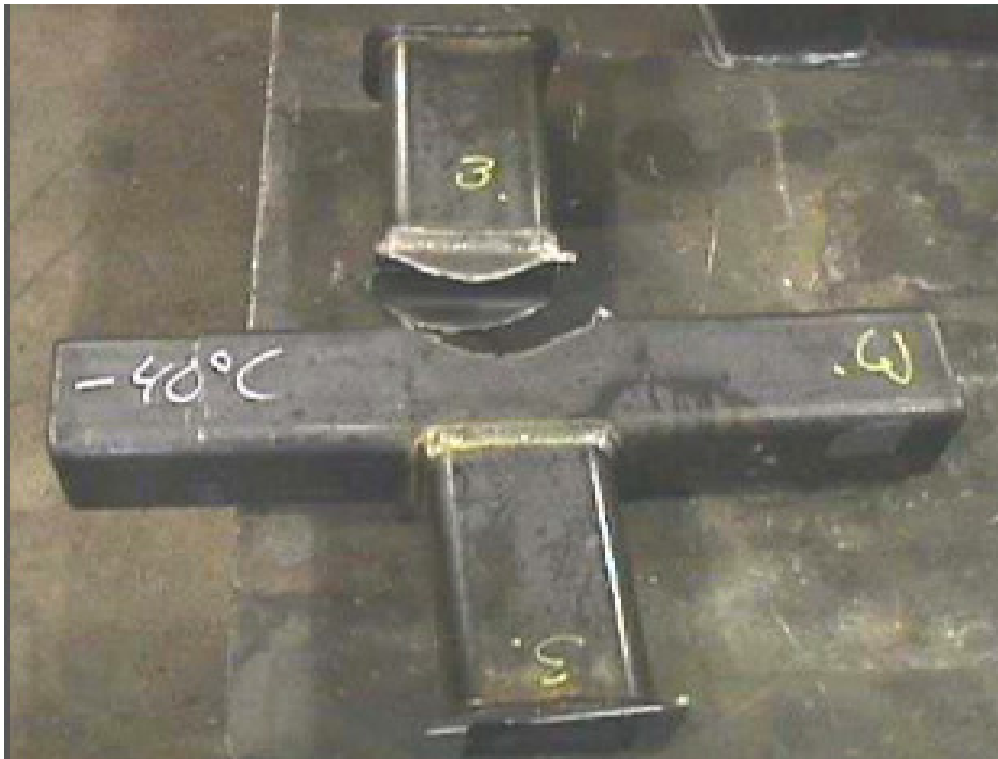
# Cold formed hollow sections

## suitability for steel construction

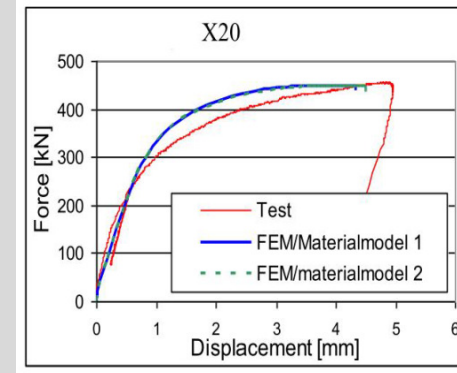
– common claims

- ▶ Not allowed to weld in corners
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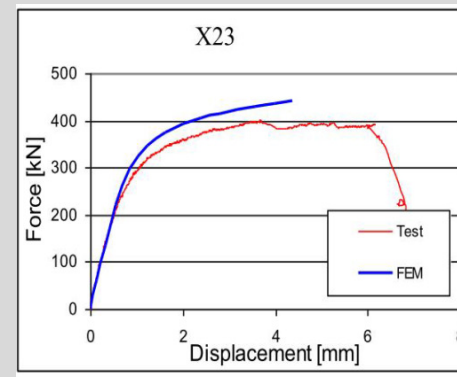
Welded joints  
 Capacity welded K- and X-joints  
 Cold formed and hot formed  
 Study and Conclusion by Lappeenranta  
 university



[5] Björk, T.: Ductility and ultimate strength of cold-formed rectangular hollow section joints at subzero temperatures. Acta Universitatis Lappeenrantaensis 233, Dissertation, Lappeenranta University of Technology, 2005.



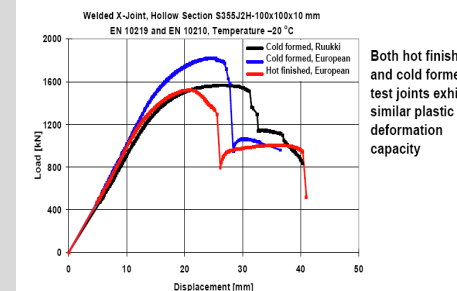
Cold



Hot

Welded joints  
 Structural behaviour of welded X-joints

Pirttijoki J. "The X-Joint tests of cold and hot formed structural hollow sections at low ambient temperatures"



Both hot finished and cold formed test joints exhibit similar plastic deformation capacity

- Cold europe

- Cold SSAB

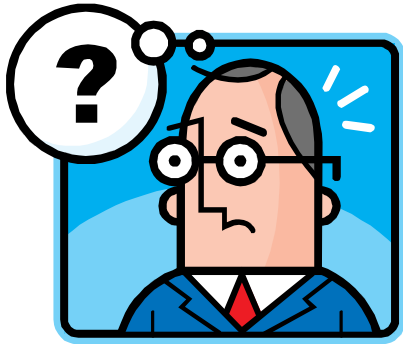
- Hot



# Deformation- and load capacity welded joints

## Conclusion

- ▶ Production method, cold- or hot forming, doesn't result in any significant differences in the performance of welded joints
- ▶ Correctly designed and welded joints made from cold formed EN 10219 hollow sections (SSAB) fullfills the demands on deformation- and load bearing capacity even at low temperatures (-40 - -60°C)



# Cold formed hollow sections

## suitability for steel construction

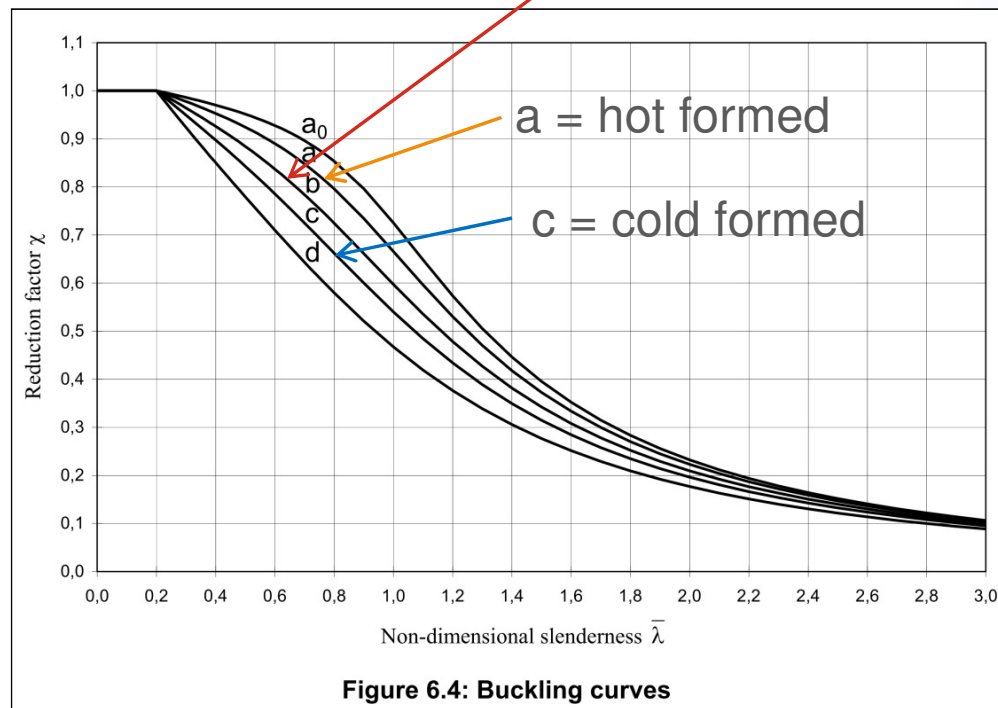
– common claims

- ▶ Not allowed to weld in corners
- ▶ Insufficient deformation capacities in welded joints
- ▶ **Insufficient buckling resistance compared to hot formed**
- ▶ Insufficient fatigue strength
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# Buckling resistance

curve "a" vs curve "c", EN 1993-1-1

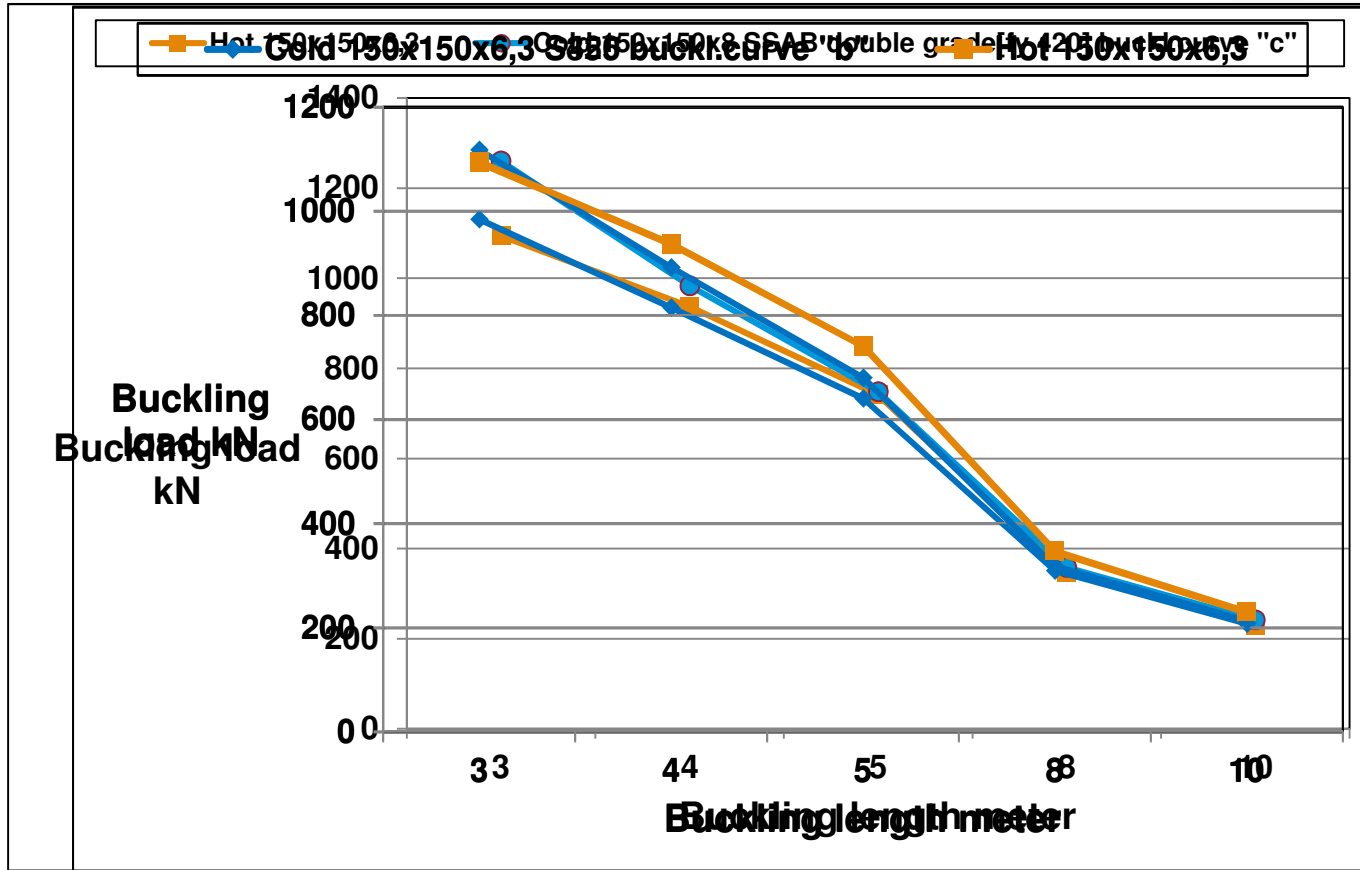
**b = cold formed SSAB**  
Requires project specific approval from authorities.  
SSAB provides document



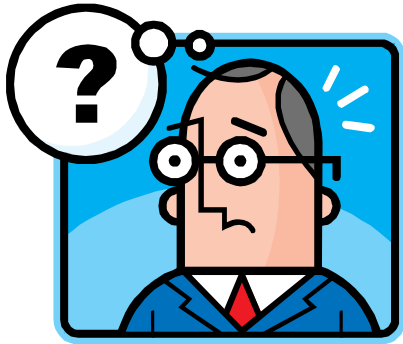
Curve "c" gives up to 22% lower buckling resistance than curve "a"

Source: EN 1993-1-1, rev 2005, Figure 6.4.

# Buckling resistance



Equal or higher capacity with lower cost  
with SSAB double grade fy 420 MPa



# Cold formed hollow sections

## suitability for steel construction

– common claims

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# Fatigue strength cold formed hollow sections

- ▶ Joints of hollow sections has the same fatigue strength in eurocode and standards regardless of product, hot- or cold formed, tested with traditional method as well as hotspot method
- ▶ In Eurocode 3, part 1-9, as well as in CIDECT Design guide no 8, is no difference made between hot- and cold formed hollow sections

# Utmattningshållfasthet hot formed and cold formed

(eight international fatigue congress 2002)

J. Ö. ÖSTERHOLM · SSAB

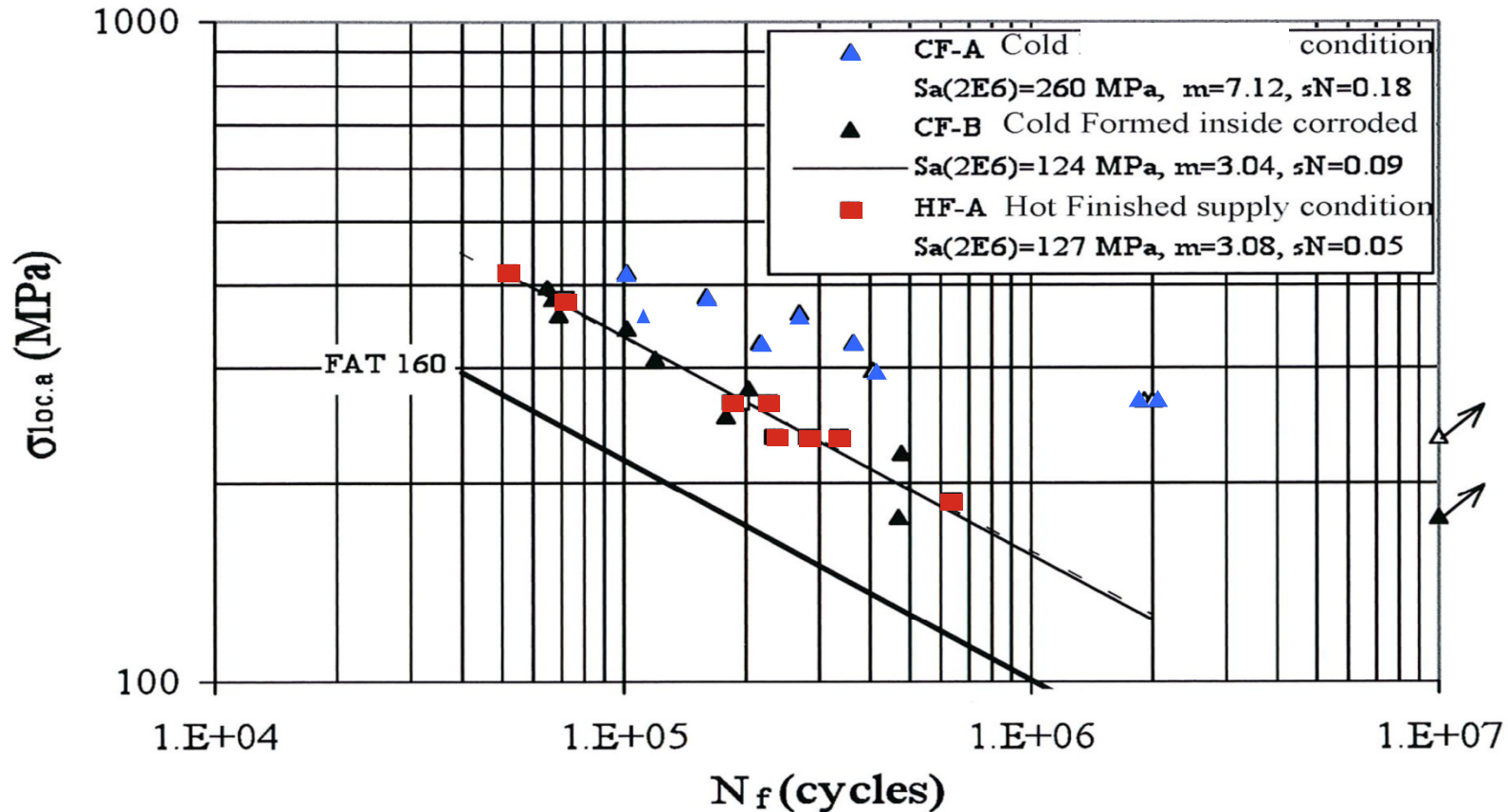
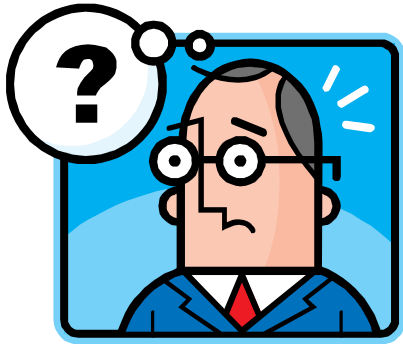


Fig. 9. Fatigue strength of grade S355J2H rectangular hollow section corners as a function of nominal normal stress amplitude, Bäckström et al. [12]

[12] Bäckström, M., Savolainen, M., Ilvonen, R., Laitinen, R.: A new fatigue testing method for the corners of structural hollow sections. Proceedings of Fatigue 2002, Eighth International Fatigue Congress, Stockholm, Sweden, June 2-7, 2002, pp. 277-302.



# Cold formed hollow sections

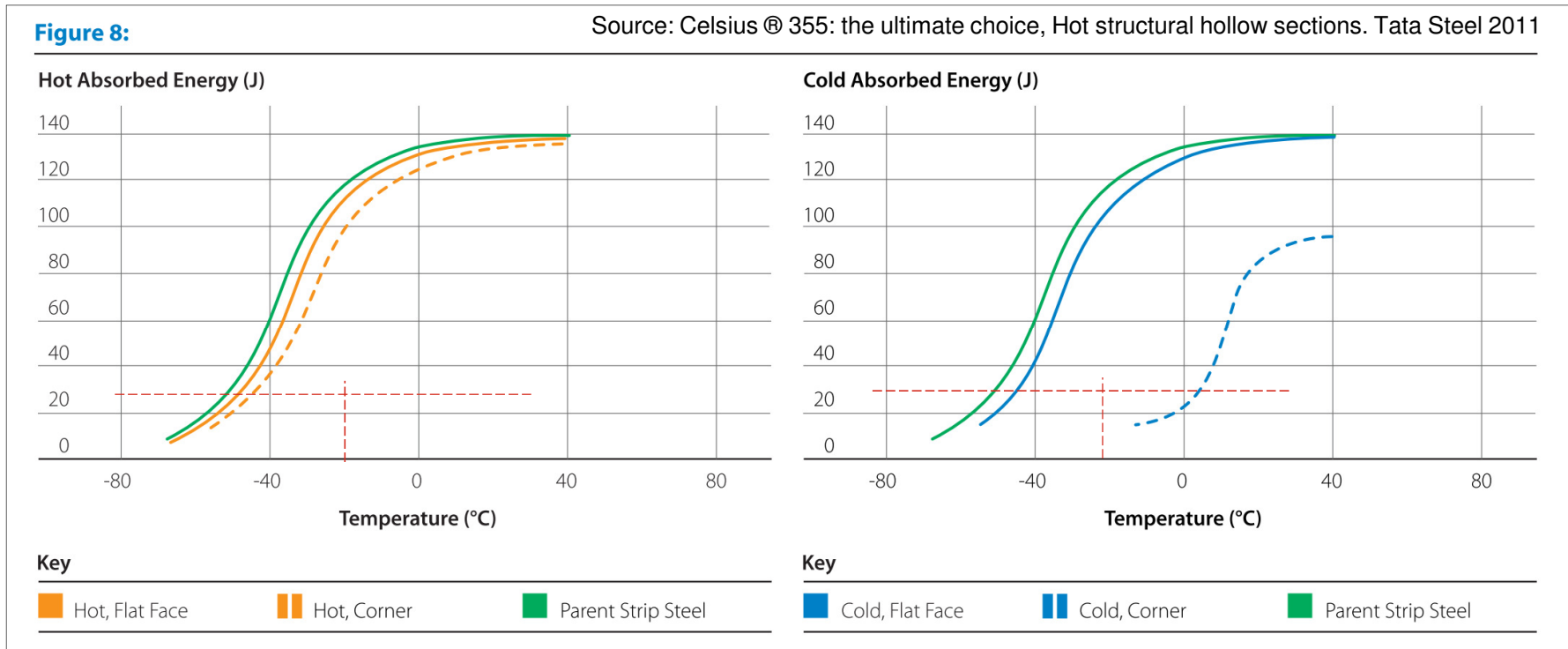
## suitability for steel construction

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# Impact strength at low temperatures

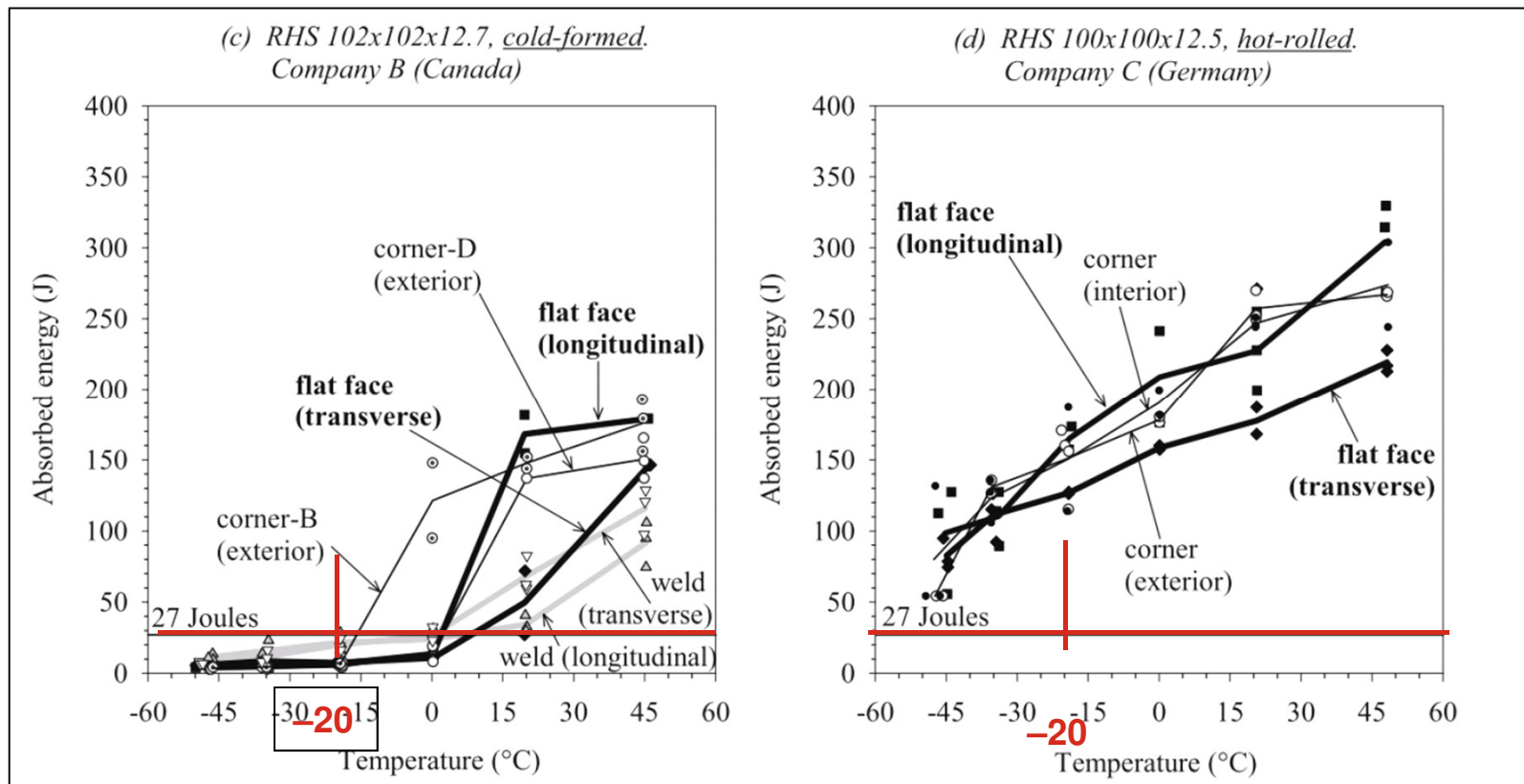
## Hot formed hollow section producers reasoning



**Claim:** Impact strength at the corners of cold formed hollow sections is reduced to non approved level

# Impact strength cold- and hot formed hollow sections

## Report 1B-2/03, CIDECT, Geneva, 2003



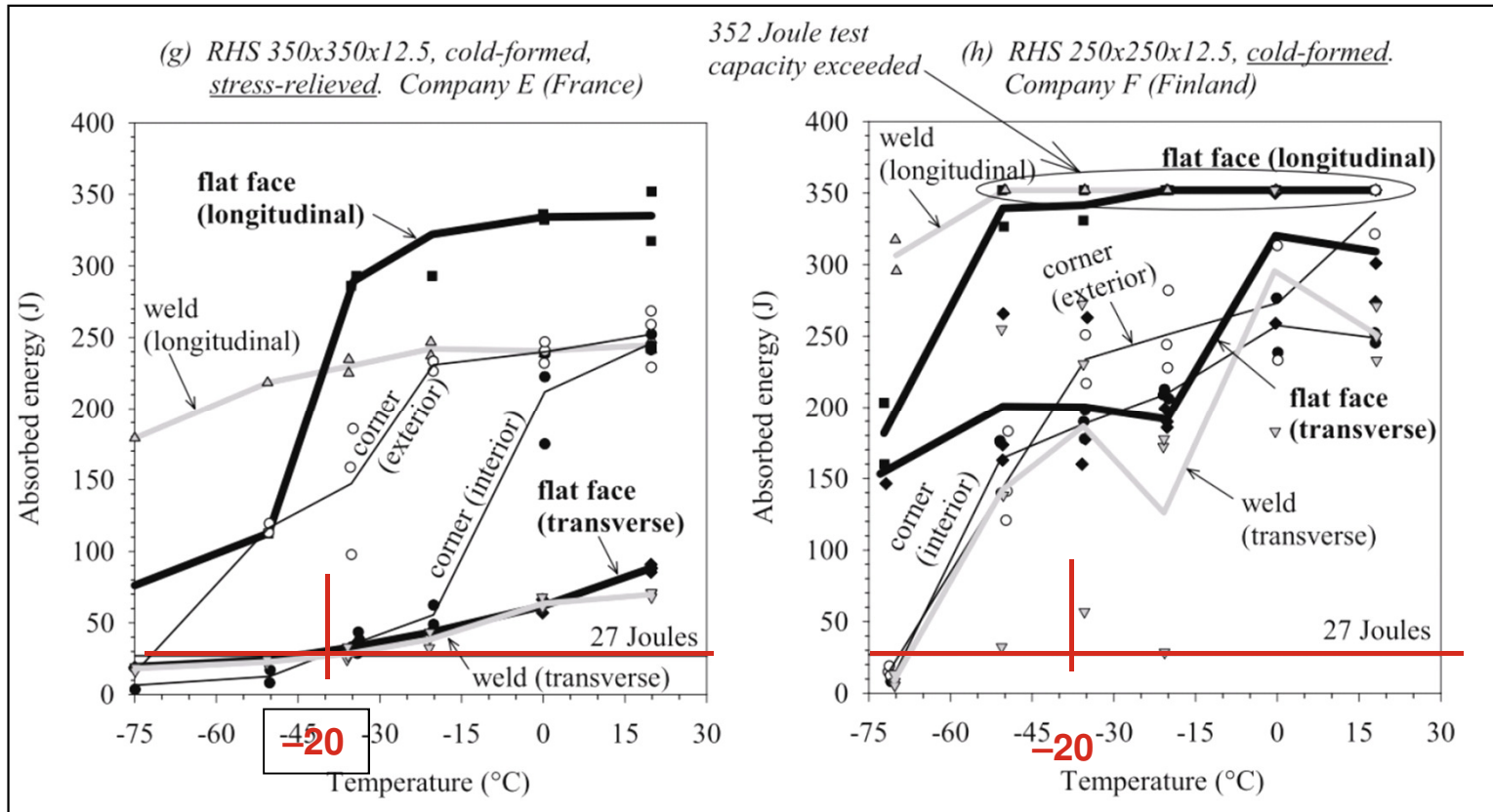
**(c) Does not satisfy any EN 10219 steel grade**

**(d) Satisfies EN 10210 steel grade S355J2H in all locations of cross section**



# Impact strength cold- and hot formed hollow sections

## Report 1B-2/03, CIDECT, Geneva, 2003



(g) Satisfies EN 10210 steel grade S355J2H in all locations of cross section

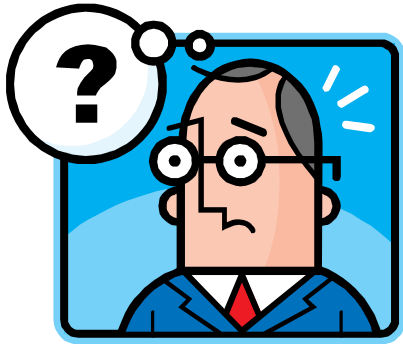
(h) Satisfies and exceeds by far EN 10219 steel grade S355J2H in all locations of cross section

# Impact strength at low temperatures

## Conclusion

- ▶ Products on the market shows a variety of results
- ▶ Impact strength depends on producer
- ▶ Production method, **hot- or cold forming**, is not the primary factor determining the impact strength at low temperatures
  
- ▶ Impact strength on SSAB double grade hollow sections satisfies by far EN10219 steel grade S355J2H and S420 MH in all locations of cross section

Source: Ritakallio, P.O.: Coldformed highstrength tubes for structural applications. Steel Construction, 5 (2012), No. 3, pp. 158167.



# Cold formed hollow sections

## suitability for steel construction

– common claims

- ▶ Not allowed to weld in corners
- ▶ Insufficient deformation capacities in welded joints
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## Properties at high temperatures



CIDECT\* Design guide No.4 concludes that differences in change of properties at fire between cold- and hot formed are small. Therefore no difference is made when dimensioning for fire, not for unfilled and not for concrete filled hollow sections

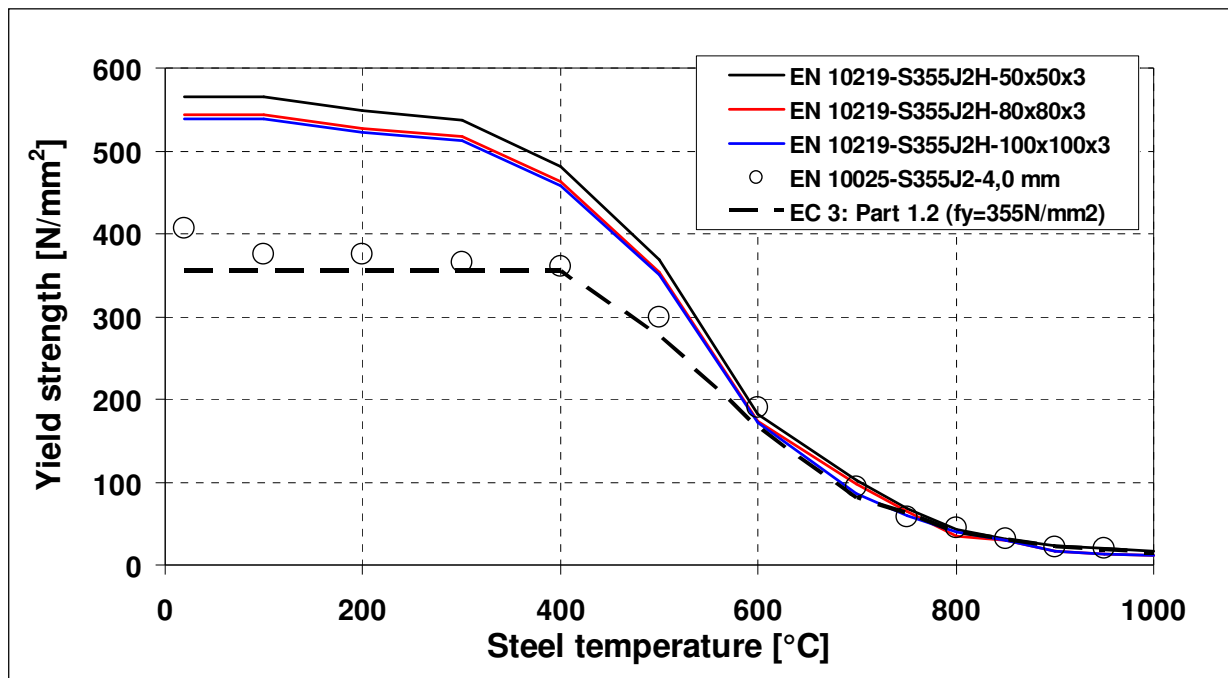
\*CIDECT= organisation providing design rules for hollow sections

Source: Puthli, R.,Packer, J. A.: Structural design using cold-formed hollow sections, Steel Construction 6 (2013), No. 2, pp 150-157.

# Cold formed hollow sections

## Resistance to fire

### SSAB S355J2H



**Loss of strength at fire develops slowly and evenly. No indication of unpredictable loss of strength**

Source: Outinen J., Mäkeläinen P.: Effect of High Temperature on Mechanical Properties of Cold-Formed Structural Steel. Ninth International Symposium and Euroconference on Tubular Structures, Düsseldorf, Germany. Proceedings book: Tubular Structures IX, Edited by: Puthli, R., Herion, S., A. A. Balkema, pp. 439-444, Niederlande, 2001.

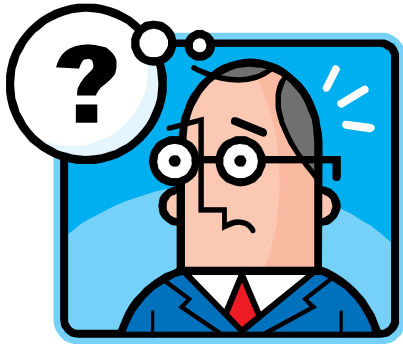
# Cold formed hollow sections

## Properties at high temperatures

### Conclusion

- ▶ No unpredictable loss of strength at high temperatures
- ▶ Withstands heating and cooling without significant loss of yield strength, up to 580°C
- ▶ Can be flame straightened if needed
- ▶ Has as good resistance to fire as hot formed hollow sections
- ▶ Can safely be used according to present construction rules





# Cold formed hollow sections

## suitability for steel construction

– common claims

- ▶ Not allowed to weld in corners
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# Corner radius hot- and cold formed

## What does the standards say?



### EN 10210 Hot formed

External corner profile ( $C_1$ , $C_2$ or $R$ ) <sup>f</sup>	—	3T maximum at each corner
--	---	---------------------------

### EN 10219 Cold formed

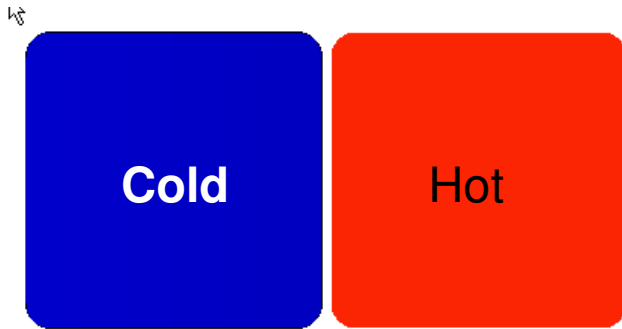
Thickness $T$	External corner profile $C_1$ , $C_2$ or $R^a$
$T \leq 6$	1,6 $T$ to 2,4 $T$
$6 < T \leq 10$	2,0 $T$ to 3,0 $T$
$10 < T$	2,4 $T$ to 3,6 $T$

### Typical values SSAB

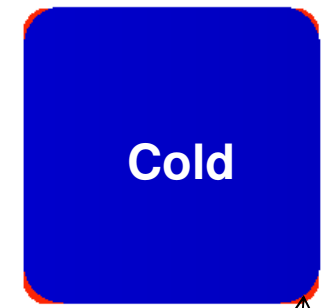
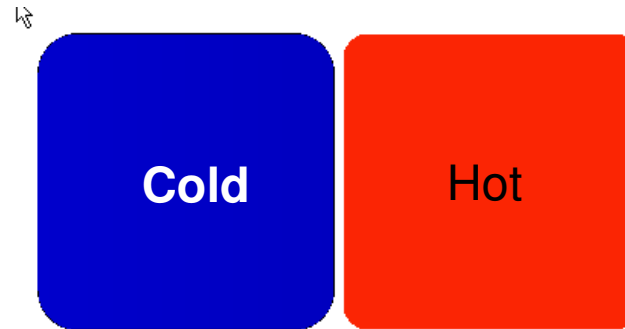
$T \leq 6$ mm	2 T
$T > 6$ mm $\leq 10$ mm	2,5 T
$T > 10$ mm	3 T

# Corner radius cold formed and hot formed $R=2 \times T$

150 x 150 x 6

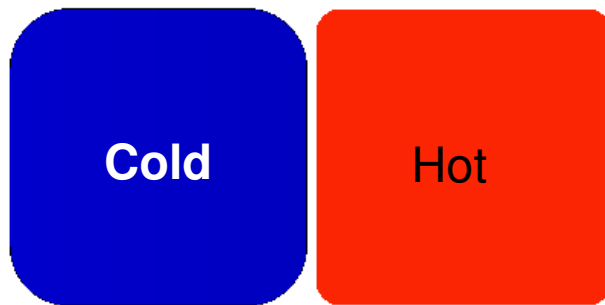


150 x 150 x 8



Hot

150 x 150 x 10



Hot

# Frames – corner radius

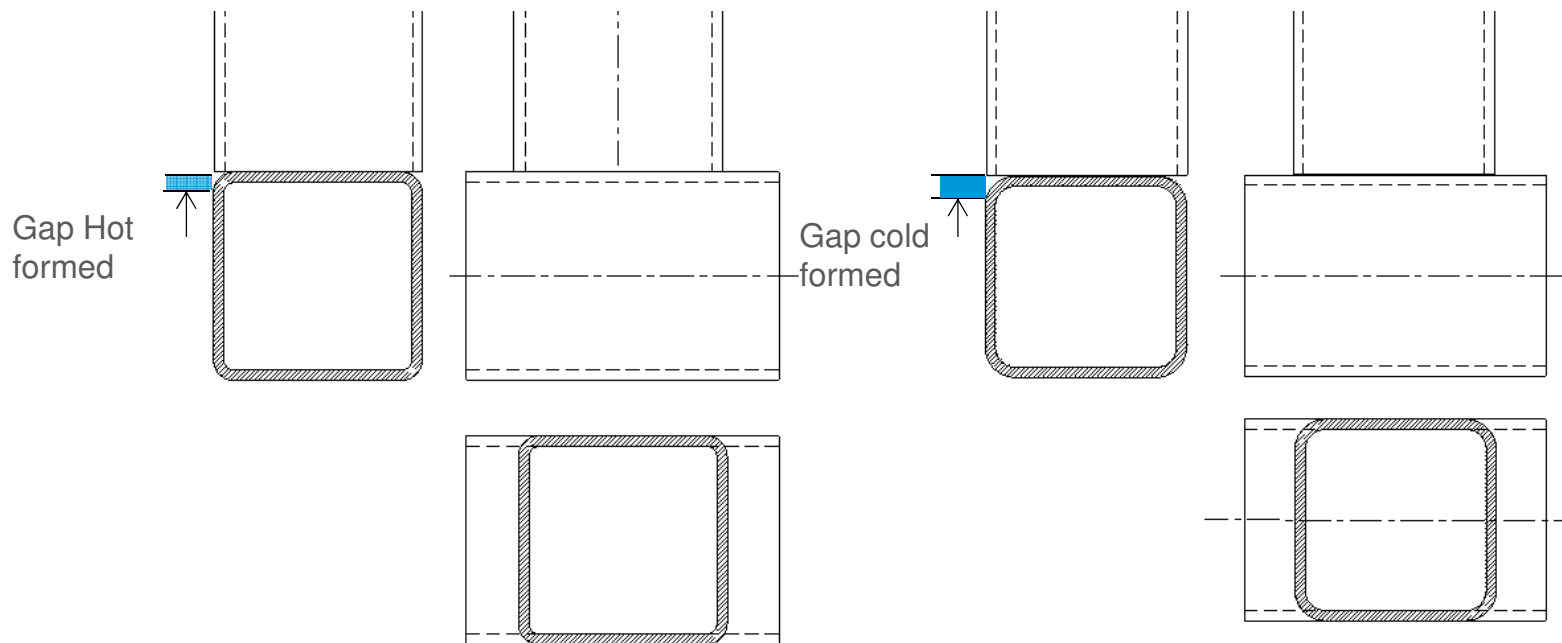


FRAME

Width ratio frame – column=1

Hot formed 200x200x10

Cold formed 200x200x10



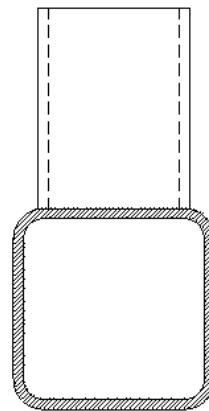
# Frames – corner radius

Potential problem can be solved by planning and designing for cold formed



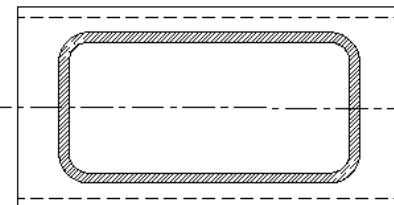
FRAME

Different cross section with same load bearing capacity



Cold 300x150x10

Cold 200x200x10

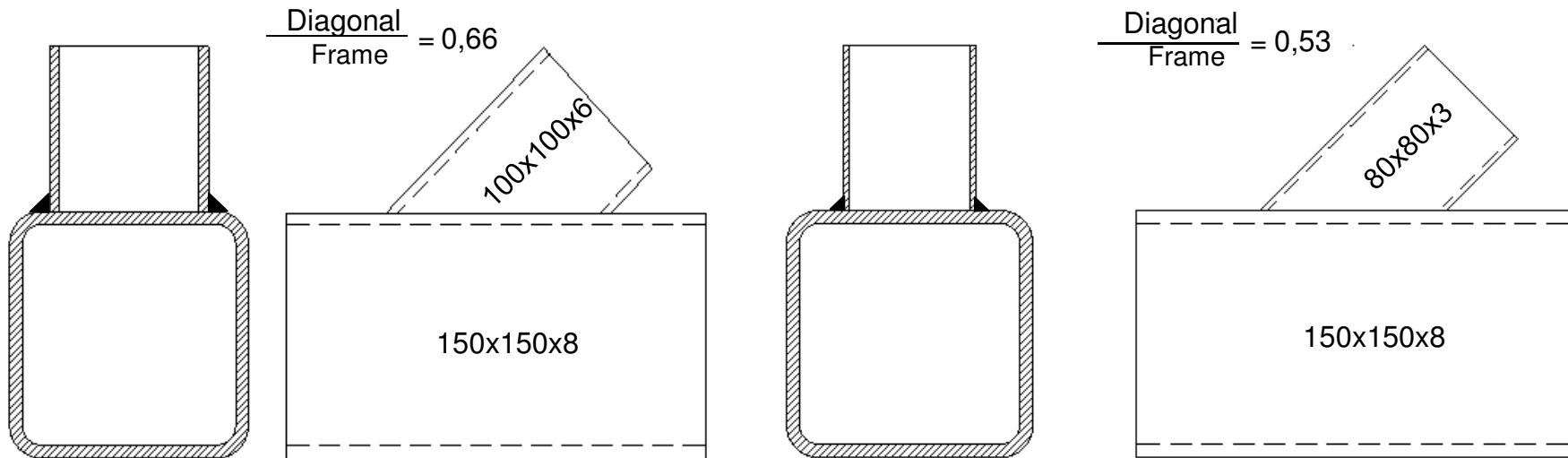


# Cold formed hollow sections in trusses

Recommended ratios diagonal/frame is 0,4-0,7

Diagonals can be welded against flat side

[Puhtli, Packer Steel Construction no 2]



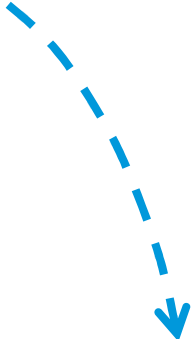
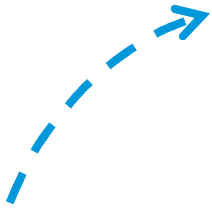
# Conclusion

- ▶ Both products are treated generally **equal in Eurode 3 and EN 1090**
- ▶ Provided the cold formed hollow sections used are produced according to european standards and the design is planned as made of cold formed then cold formed hollow sections are a **suitable and safe** design element for **all construction purposes**
- ▶ Cold formed hollow sections are a **cost effective** solution in the choice between hot formed and cold formed
- ▶ SSAB:s double grade cold formed hollow sections conform to and exceed the requirements of european harmonized standard EN 10219-1&2 and represent a **safe, reliable and versatile** construction element for **environmentally sound and competitive solutions**





Cold formed -25%  
+  
SSAB double grade  
15% weight reduction  
and mtrl cost



# Cold formed hollow section in CorTen steel

- ▶ CorTen steel forms a self sealing protective corrosion layer
- ▶ CorTen steel can be used in outdoor structures without any separate surface treatment in rural and industrial environments
- ▶ Weather resistant steel can be painted using the same methods applied in painting ordinary steels
- ▶ Coat of paint can last twice as long as a coating on ordinary steel.
- ▶ If flaking of paint occurs there is still a protective layer preventing corrosion
- ▶ CorTen cold formed hollow sections available in S355J2H, S500 MH, S700 MH



THANK  
YOU!