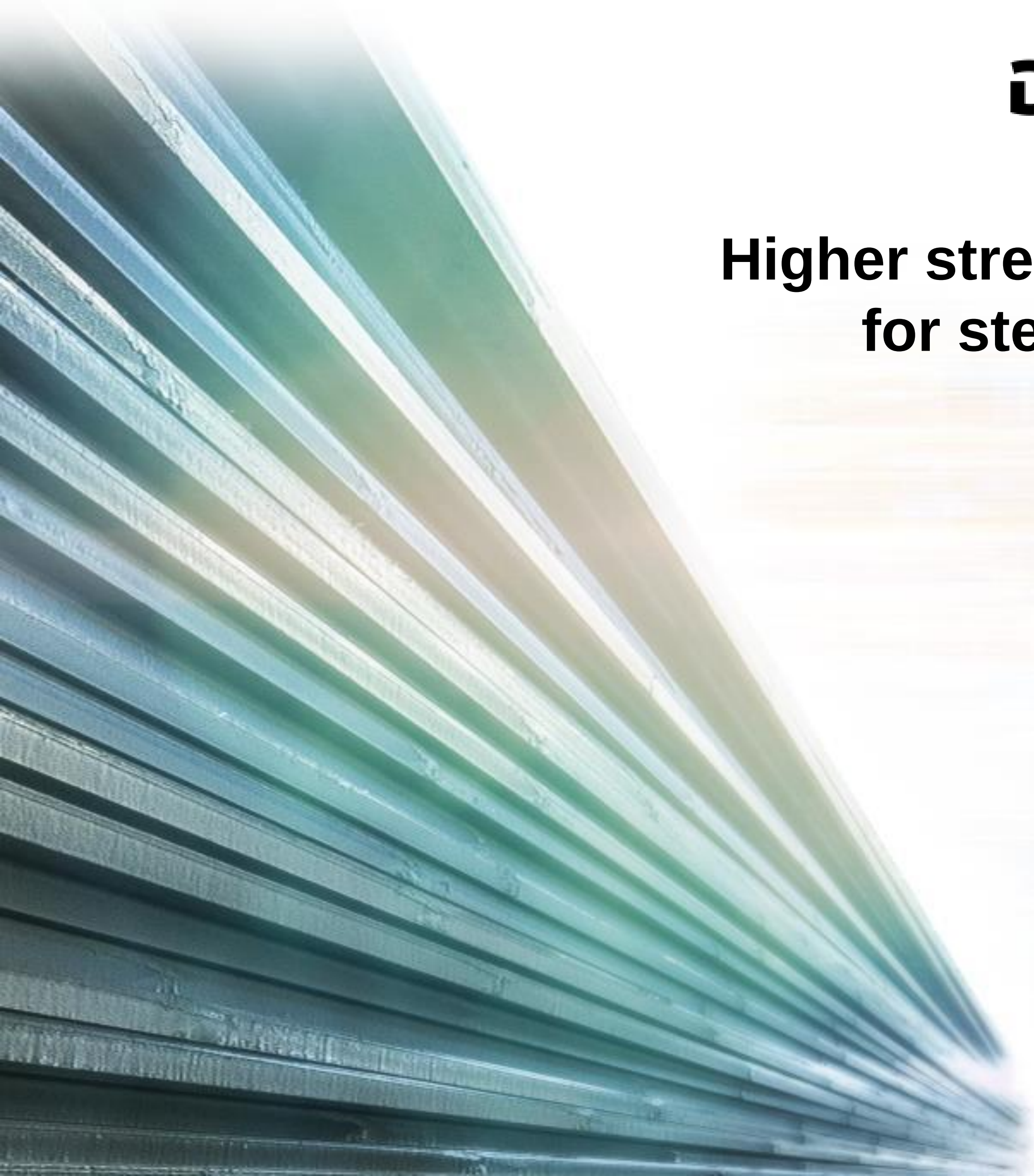


Higher strength steel plate for steel construction

Dr. Tobias Lehnert

How are higher strength steels produced?

Different routes to obtain higher strength in steel up to 500 MPa:

- **Normalising (N)**
  - ⇒ Higher carbon equivalent, decreasing weldability
  - ⇒ increasing brittle fracture tendency
- **Thermo-Mechanically Rolling (M)**
  - ⇒ mainly up to S500
  - ⇒ low carbon equivalent ⇨ excellent weldability
- **Quenching and Tempering (Q)**
  - ⇒ most commonly used method to produce high strength steel
  - ⇒ additional heat treatment
  - ⇒ applied after hot rolling
  - ⇒ up to 1300 MPa, in steel construction up to S690QL
  - ⇒ good weldability

Thermomechanically rolled steels in EN 10025

In general:

S + yield strength class + toughness class

in MPa at lowest thickness

3. Thermomechanically rolled fine grained steels acc. to EN 10025-4 (NEW 2019)

- Yield strength classes: 275, 355, 420, 460, 500
- Toughness classes: M(L)

	Min. impact energy	Test temperature
M	40 J	-20° C
ML	27 J	-50° C

- Examples: S 355 M, S 460 ML

- **All grades now up to 150 mm plate thickness**
- **Plate width up to 4700 mm**
- **Plate length up to 28 m**
- **Plate weight up to 42 t**

Benefits of using high strength TM Steel

Possible Cost/time savings by using TM-steels

1. Same strength (S355 N ⇨ S355 M – S460 N ⇨ S460 M):

   => mainly applies to the **fabricator** of a steel construction

2. Transition to a higher strength grade (S355 N ⇨ S460 M):

   => mainly applies to the **designer** of a steel construction

Benefits of using high strength TM Steel

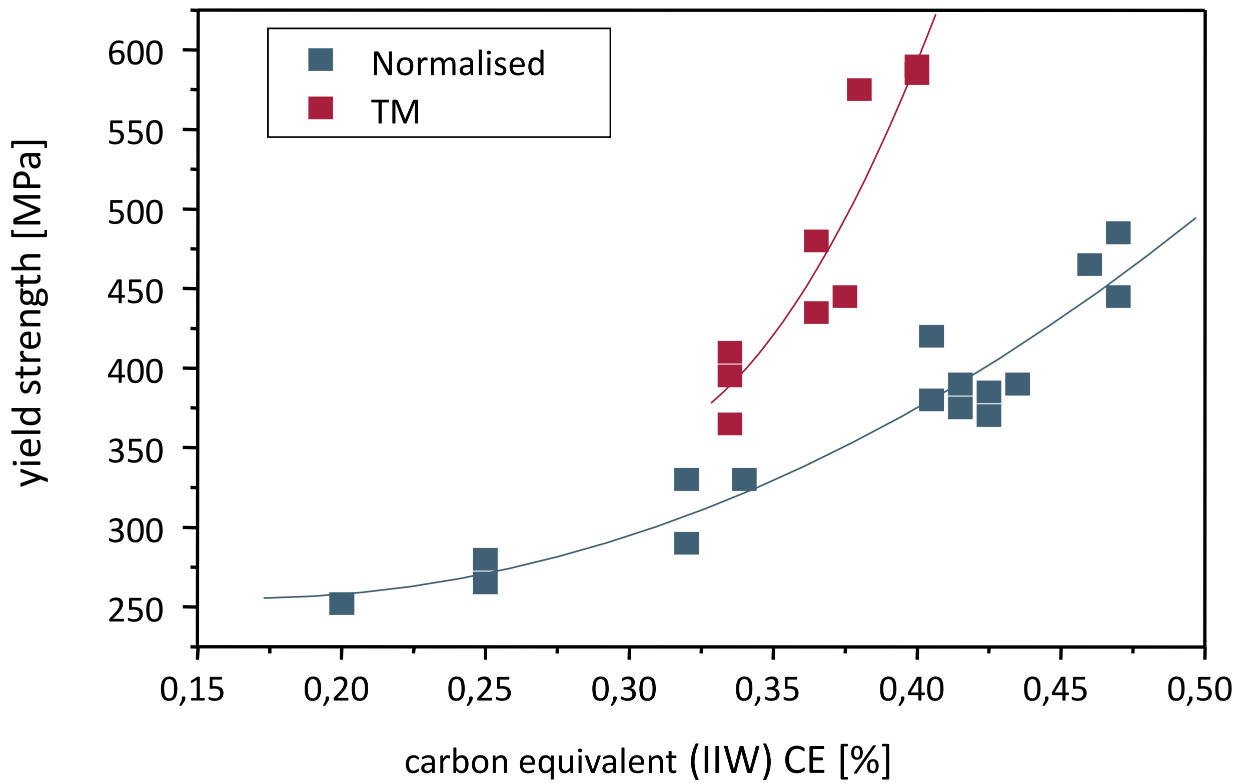
Possible Cost/time savings by using TM-steels

1. Same strength (S355 N ⇨ S355 M – S460 N ⇨ S460 M):

   => mainly applies to the **fabricator** of a steel construction

Benefits of using high strength TM Steel

Less alloying ➔ better weldability



⇨ TM allows adding strength without high alloying contents compared to normalised alternatives

DILLINGER

Benefits of using high strength TM Steel

Low alloying contents for TM-steels

Typical Carbon Equivalents for different steel grades (plate thickness 50mm)

Steel grade	typical CET /%	typical CEV /%	max. CEV /% acc. EN 10025
S355J2+N	0.31	0.42	0.45
S355M/ML	0.22	0.34	0.40
S460M/ML	0.25	0.39	0.47

Carbon equivalents:
CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15
CET = C + (Mn + Mo)/10 + (Cr + Cu)/20 + Ni/40

CE ↓

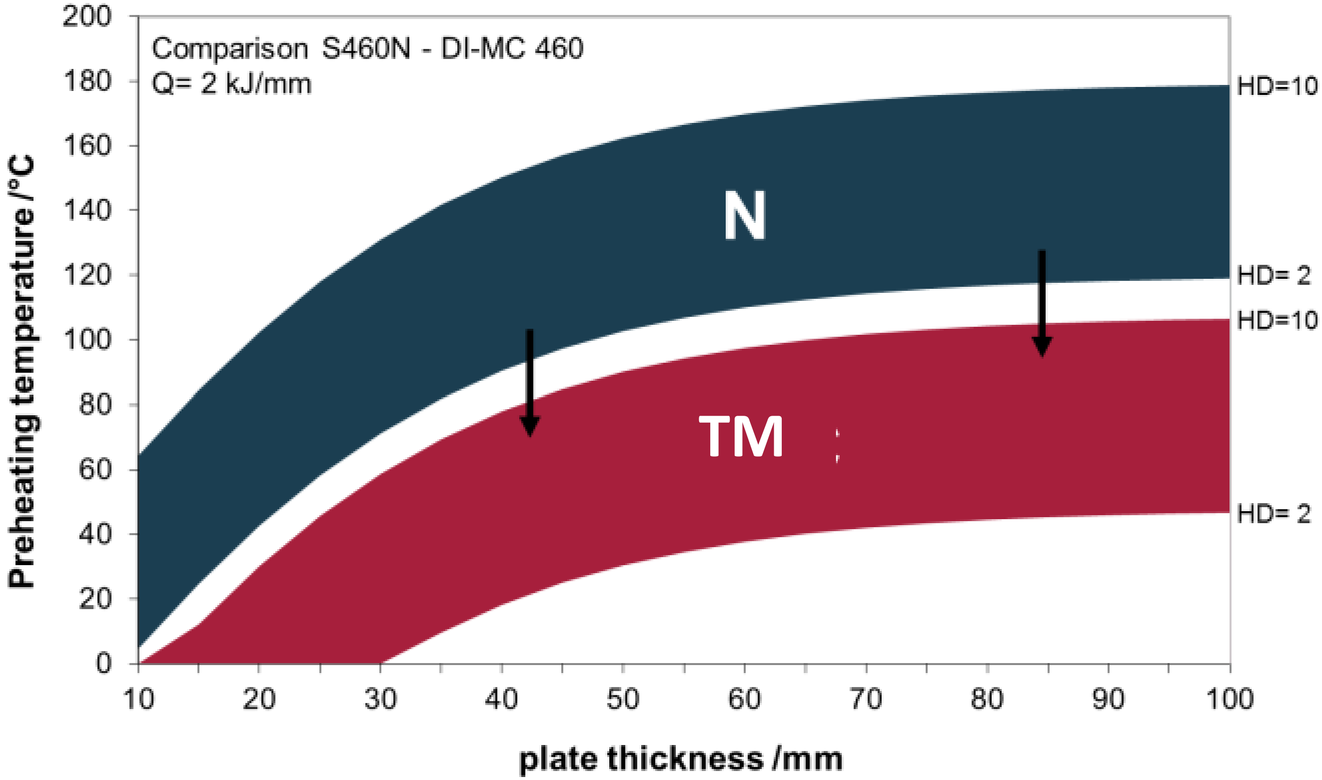
⇨ cold cracking tendency ↓
⇨ toughness in HAZ ↑

⇨ TM Steels allows high strength steel (S460M/ML) with excellent weldability

⇨ gaining strength without loosing processability, e.g. preheating

Benefits of using high strength TM Steel

Reduction of preheating according to EN 1011-2 method B



Benefits of using high strength TM Steel

Possible Cost/time savings by using TM-steels

1. Same strength (S355 N ⇨ S355 M – S460 N ⇨ S460 M):

Avoidance of preheating

⇨ Less consumption of electric power for preheating
⇨ Less time heating up
⇨ Shorter set up times due reduced cooling times as main saving
⇨ Also in terms of job safety, low preheating is beneficial
  – no hot surfaces and no handling with gas
  – Better working conditions

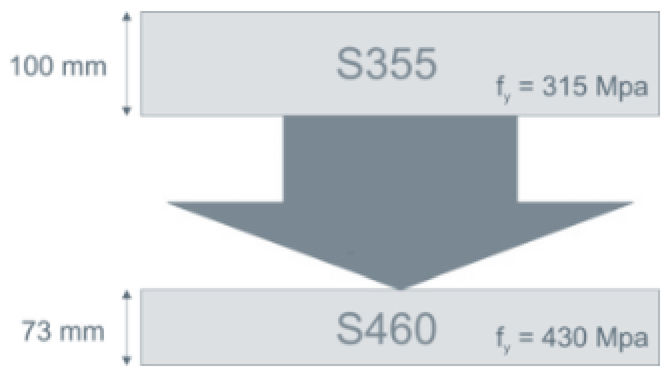
High toughness values

⇨ Improvement of productivity by faster welding process
⇨ Additional safety for construction

Benefits of using high strength TM Steel

Possible Cost/time savings by using TM-steels

2. Transition to a higher strength grade (S355 N ⇨ S460 M):



Reduction of thickness: up to 30 %

⇨ Multiple effects on the cost and eco-balance

⇨ less material ⇨ lighter construction

⇨ lower component weight ⇨ bigger assembly units

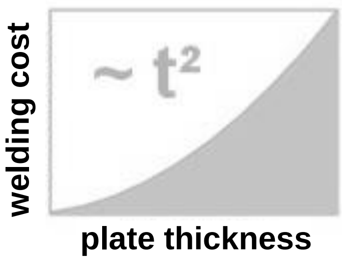
⇨ faster assembly and optimized transportation

⇨ Sustainable and highly economically efficient

Benefits of using high strength TM Steel

Possible Cost/time savings by using TM-steels

2. Transition to a higher strength grade (S355 N ⇨ S460 M):

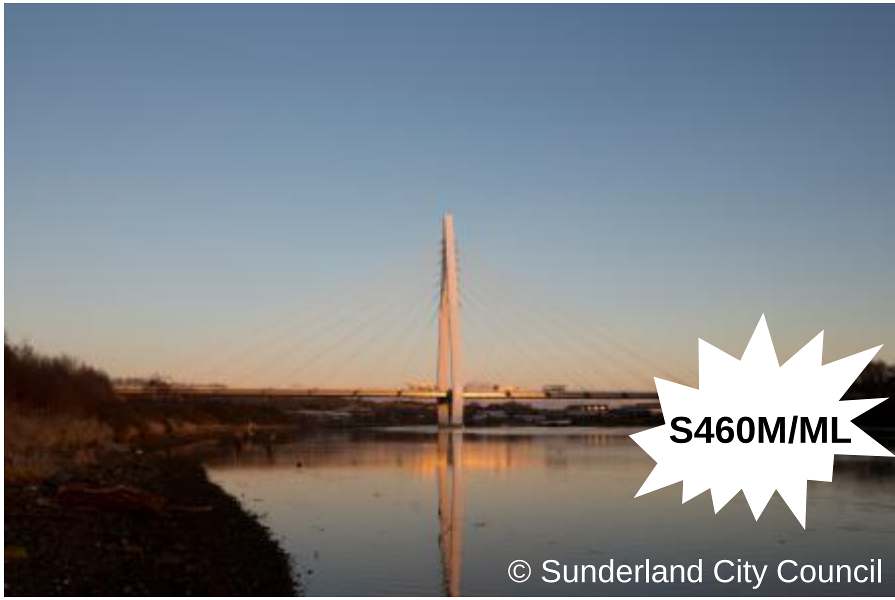


Higher strength + TM, e.g. S460M/ML

⇨ unchanged good weldability

- ⇨ reduced weld seam volume
- ⇨ less welding consumables
- ⇨ reduction of welding time

⇨ reduced overall welding cost



Carrington Bridge, UK

~ 800 t of high strength **weathering** steel S460J5W+M (DIWETEN 460 + M)

⇨ allowed three-span bridge vs. originally planned six-span bridge

- ⇨ 3 piers avoided

⇨ 15% less steel used

⇨ ~six weeks reduction in construction time

A6 Bridge Heilbronn, Germany

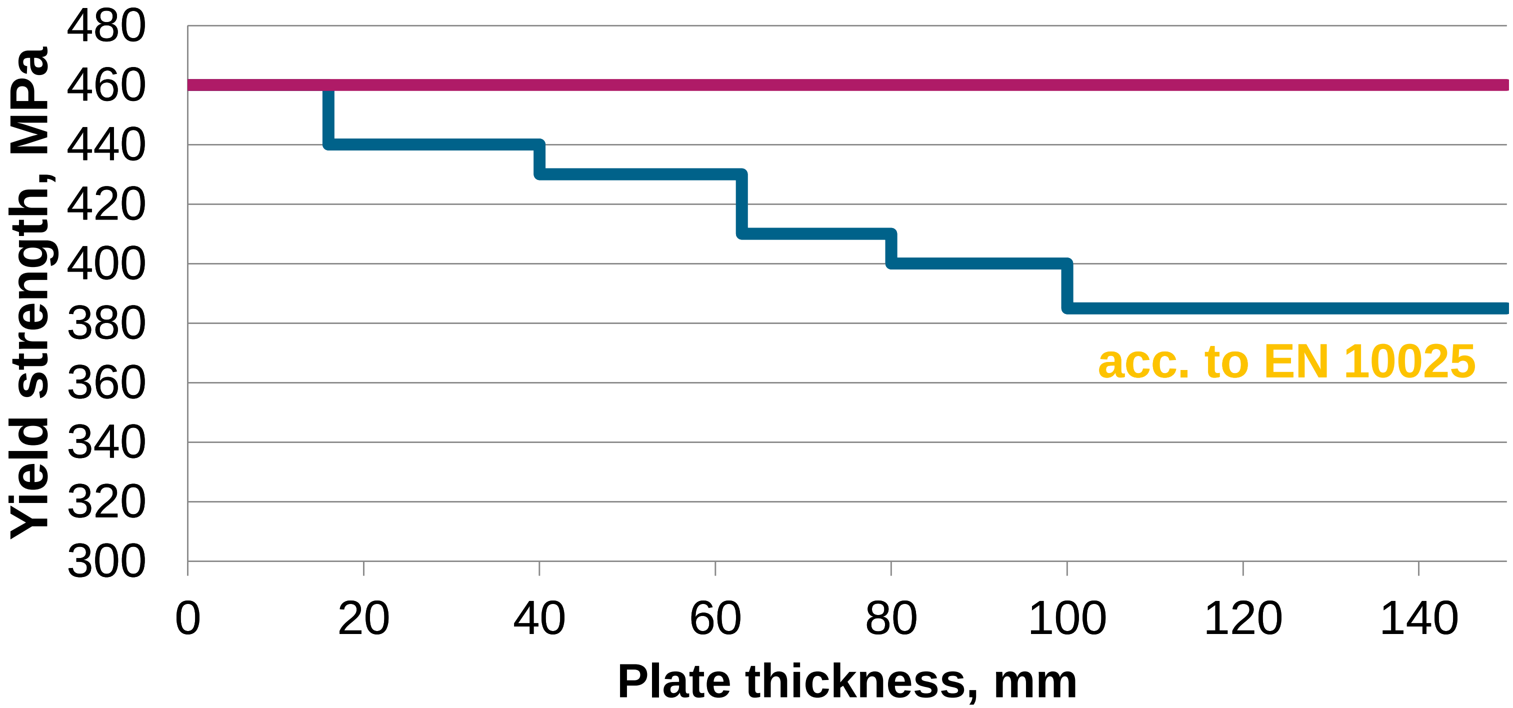
- ~ 5,000 t of high strength TM steel S460ML
- **additionally** with full yield strength (460 MPa) even in 110 mm

⇨ lighter construction

⇨ maximum plate thickness reduced for better brittle fracture performance

Possibilities with modern TM steels

OPTIONALLY with constant tensile properties (yield strength as well as tensile strength) from 8 mm to 150 mm available



⇨ calculation with R_{eh}=460 MPa independent from thickness

⇨ further reduction of plate thickness possible

⇨ similar availability also for rolled sections

Examples for high strength TM Steels

Aircraft service hangar, Germany

A380 Halle auf dem Frankfurter Flughafen

Foto: Jens Görlich / Lufthansa 0712_A380_HALLI
Nur für redaktionelle Zwecke / For editorial purposes

A380-Halle, Anhebung des Hallendaches in Frankfurt

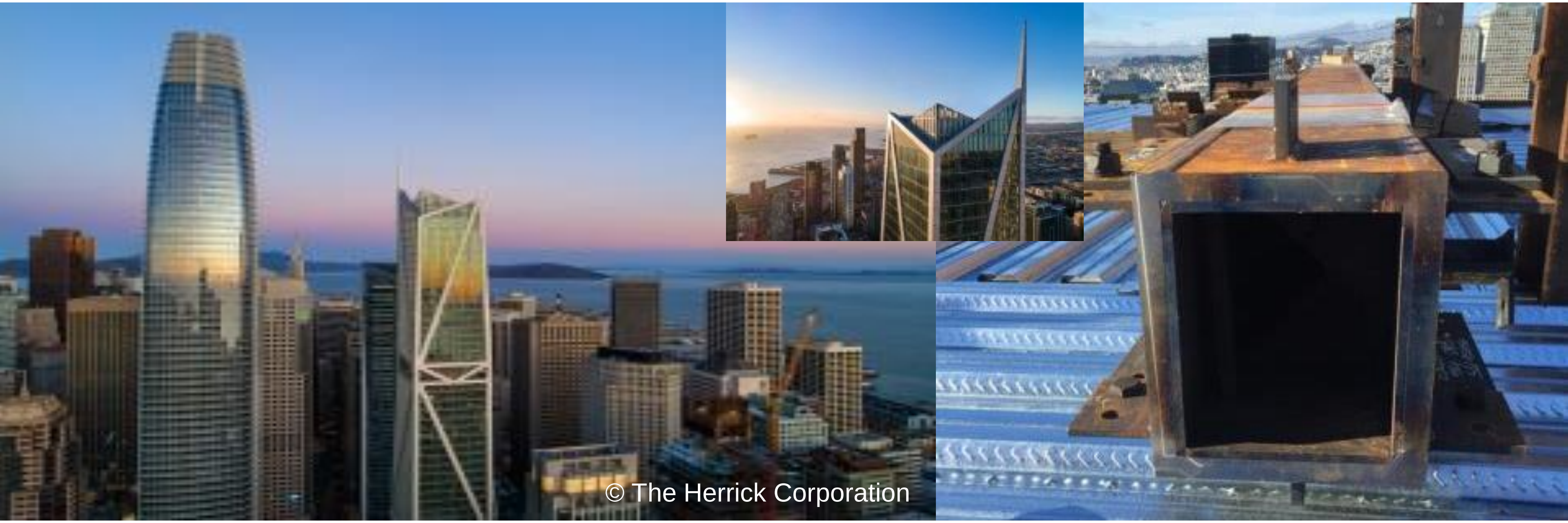
Foto: Jens Görlich / Lufthansa 070425_A380_HALLENDACH
Nur für redaktionelle Zwecke / For editorial purposes only

- ~1,100 t of high strength TM steel S460ML
- again additionally with full yield strength 460 MPa even in 120 mm

⇨ **lighter construction**

⇨ main lattice girders with 170 and 180 meter spans

181 Fremont Tower, USA



- ~3,700 t of high strength TM steel A1066-65/A572-65 ~ S460M

⇨ up to 125 mm

Hudson Yard Project, USA

- ~9,000 t of high strength TM steel A1066-65/A572-65 ~ S460M

⇨ solid steel columns

⇨ higher strength allowed smaller column footprint between railtracks

Examples for high strength TM Steels

Le Monde Headquarter, France

- ~ 600 t of high strength TM steel S460M/ML

⇨ “bridge” building

⇨ up to a thickness of 140 mm with special permission

⇨ new EN 10025-4:2019 now also defines up to 150 mm

So S460 quite well established,…

…many projects all over the world benefit already from high strength TM steel as S460M/ML

➪ the next step: S690 for more strength?

- **Normalising (N)**
  - ⇒ Higher carbon equivalent, decreasing weldability
  - ⇒ increasing brittle fracture tendency
- **Thermo-Mechanically Rolling (M)**
  - ⇒ mainly up to S500
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  - ⇒ most commonly used method to produce high strength steel
  - ⇒ additional heat treatment
  - ⇒ applied after hot rolling
  - ⇒ up to 1300 MPa, in steel construction up to S690QL
  - ⇒ good weldability

Quenched and tempered steels in EN 10025

In general:

S + yield strength class + toughness class

in MPa at lowest thickness

5. Quenched and tempered fine grain steels acc. to EN 10025-6

- Yield strength classes: 460, 500, 550, 620, 690, 890, 960
- toughness classes: Q(L)(1)

	Min. impact energy	Test temperature
Q	30 J	-20° C
QL	30 J	-40° C
QL1	30 J	-60° C

- Examples: S 500 Q, S 460 QL, S 690 QL1

- **Plate thickness up to 290 mm**
- **Plate width up to 4400 mm**
- **Plate length up to 18 m**
- **Plate weight up to ~35 t**

Properties of Q+T steels – Carbon Equivalents

Typical Carbon Equivalents for different steel grades (plate thickness 50mm)

Steel grade	typical CET /%	typical CEV /%	max. CEV /% acc. EN 10025
S355J2+N	0.31	0.42	0.47
S460QL	0.30	0.43	0.47
S690QL	0.35	0.52	0.65

Carbon equivalents:
CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15
CET = C + (Mn + Mo)/10 + (Cr + Cu)/20 + Ni/40

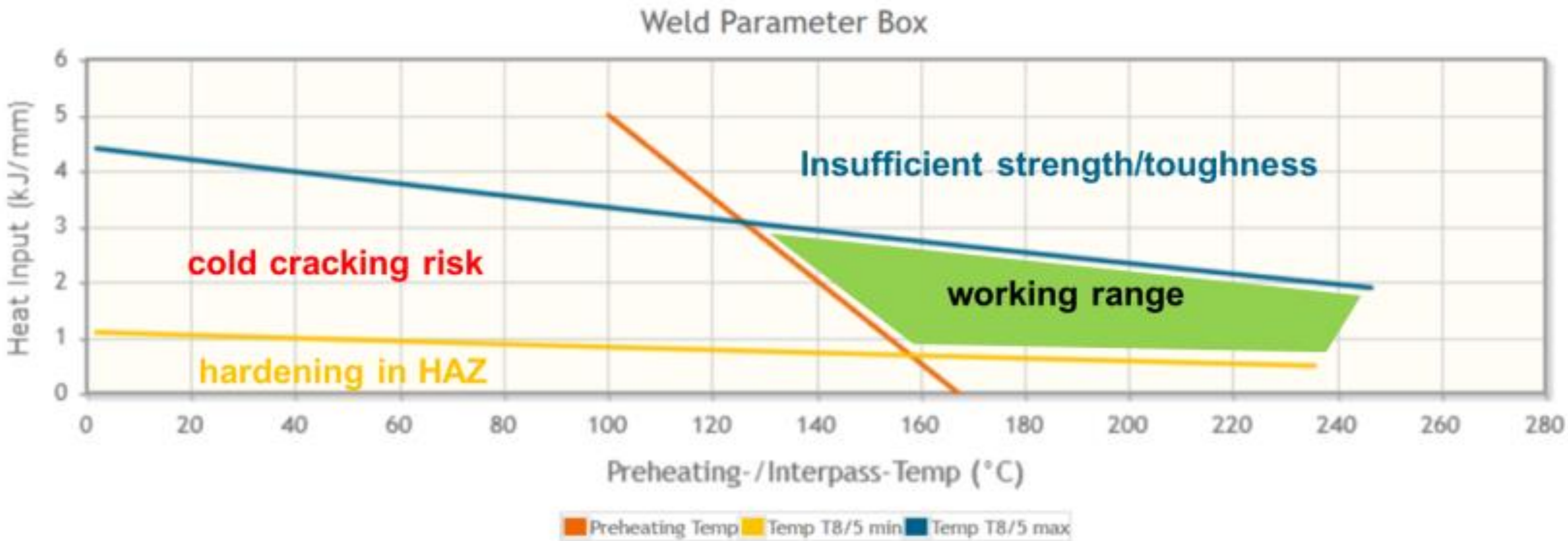
→ carbon equivalents increasing with yield strength
→ still good weldability, but measures, like preheating, to be taken

Processing - Welding of high strength steel (e.g. S690QL)

Recommended t8/5 times for high strength steels from DILLINGER

Steel grades	Min. Cooling time $t_{8/5}$ /s	Max. Cooling time $t_{8/5}$ /s
DILLIMAX 690	5	20

Processing - Welding of high strength steel (e.g. S690QL)



⇨ S690QL is easily weldable when using the right welding parameter set

Tips:

- Welding of the rootweld with softer electrode

- filled weld: If strength in weld metal is not required, softer electrode is recommended (undermatch welding)

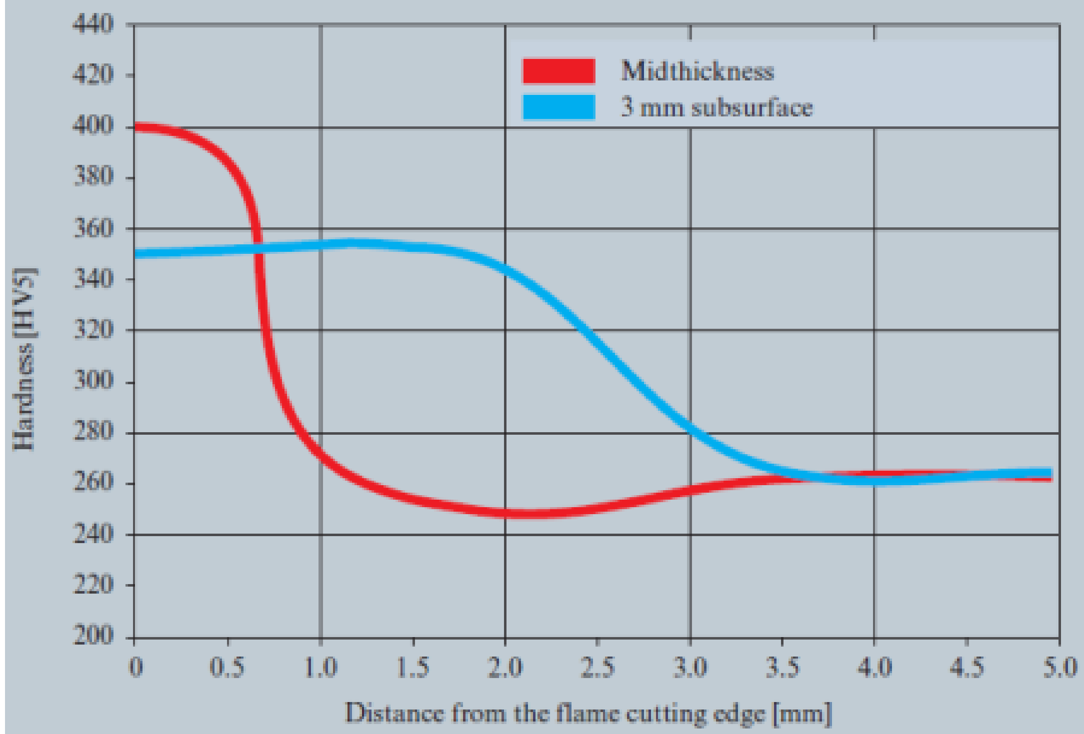
Weld parameter box can e.g. be extracted from our new E-Service Tool
http://www.dillinger.de/E-Service

Processing - Flame Cutting (e.g. S690QL)

Flame cutting is possible without difficulty

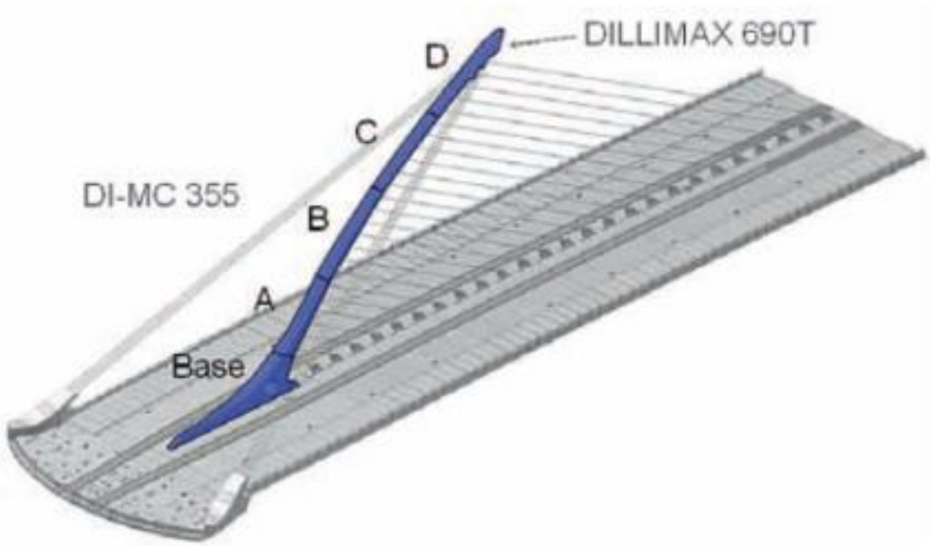
⇦ appropriate tools
⇦ proper working conditions
⇦ Preheating can be necessary

Figure 8: Typical hardening of DILLIMAX 690 at the flame cutting edge after oxycutting (plate thickness: 20-30 mm)



The preheating temperature can be extracted from our new E-Service Tool
http://www.dillinger.de/E-Service

Samuel Beckett Bridge, Ireland



- top of the pylon due to its exceptional stress situation from high strength quenched and tempered fine grain steel DILLIMAX 690T (plate thickness 180 mm)

Sony Center, Germany

Forum:

Eye bars:

- S690QL1 in 90 and 100 mm
- Reason: High compressive stresses

Rope spreading and anchoring nodes

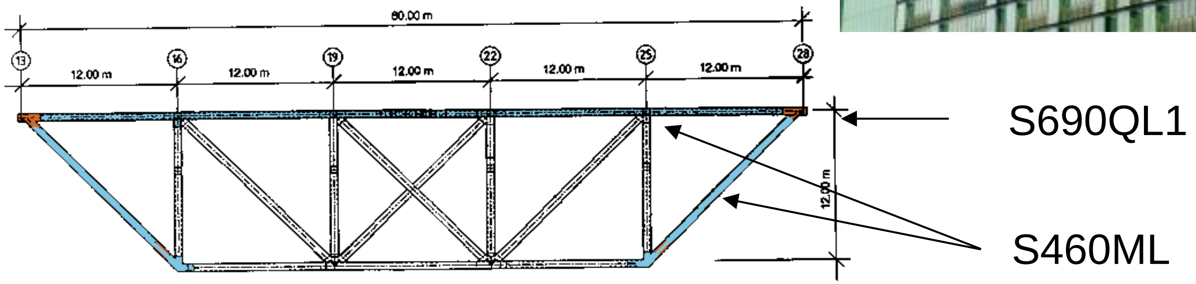
- S690QL1 up to 180 mm

Esplanade-Résidence

Two main trusses with 60 m span

Transversal truss of 5 m height

Outer nodes:



THANK YOU VERY MUCH FOR YOUR ATTENTION

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