Latest Developments in the Production and Use of High Strength Structural Steels

ArcelorMittal Commercial Sections S.A.

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Jean-Claude Gérardy – jc.gerardy@arcelormittal.com
Summary

1. Production of rolled sections
2. Tailor-Made Beams
3. HISTAR
4. Applications
Universal rolling principle

Grey patent in 1902

Universal stand

Edger stand
First 1 meter beam - June 1911
Before 1950, structural steel grades were characterised by

- low mechanical characteristics (Re=210-320 MPa)
- low toughness and ductility
- poor weldability due to high CE values and nitrogen content
Today: no blast furnace anymore
and beam blanks casters
Dog Bones – Beam Blanks
### Advantages of the EAF route versus the conventional integrated production route (Luxembourg 1993/1998)

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise</td>
<td>Limitation of acoustic emissions to 45 dB</td>
</tr>
<tr>
<td>Particles</td>
<td>Reduction of 97%</td>
</tr>
<tr>
<td>Waste</td>
<td>Reduction of 95%</td>
</tr>
<tr>
<td>Water</td>
<td>Reduction of 50%</td>
</tr>
<tr>
<td>Energy</td>
<td>Reduction of 55%</td>
</tr>
</tbody>
</table>
Historical Development

Production processes for hot-rolled steel products
1. Production of rolled sections
2. Tailor - Made Beams
3. HISTAR
4. Applications
Tailor Made Beams - 1979

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\[
\begin{align*}
& t_w \\
& \text{max.} \\
& \text{min.} \\
& \text{max.} \\
& t_f \\
& \text{min.}
\end{align*}
\]
heaviest JUMBO
1100 mm
(44”)
for bridges
Tailor Made beams

Built-up

 Rolled Section
Tailor Made beams

- > 900 high-rise buildings in the U.S.

- > 1500 high-rise buildings worldwide
1. Production of rolled sections
2. Tailor - Made Beams
3. HISTAR
4. Applications
Market in 1980

- **Satisfied market demands**
  - Strength (MPa): 500
  - Thickness (mm): 20
  - Strength (MPa): 450
  - Thickness (mm): 40
  - Strength (MPa): 400
  - Thickness (mm): 60
  - Strength (MPa): 350
  - Thickness (mm): 80
  - Strength (MPa): 300
  - Thickness (mm): 100
  - Strength (MPa): 250
  - Thickness (mm): 120

- **Not satisfied market demands**
  - Strength (MPa): 500
  - Thickness (mm): 20
  - Strength (MPa): 450
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  - Strength (MPa): 350
  - Thickness (mm): 80
  - Strength (MPa): 300
  - Thickness (mm): 100
  - Strength (MPa): 250
  - Thickness (mm): 120
  - Strength (MPa): 200
  - Thickness (mm): 140
CE Values

- *Classical TM*
- *light section*
- *heavy section*

*CE (%) vs. Re (MPa)*

- *too high CE values*
- *t_f = 140 mm*
- *t_f = 10 mm*
Layout of the GREY mill

Scrap supply
EAF
Pump house
Intermediate mill
Selective cooling
Saw
Saw
Reheating furnace
CC
Casting
Ladle furnace
Break down
Rolling mill
Finishing mill
QST
Selective cooling
Selective Cooling

Ar

Rolling with selective cooling

Classical rolling

Temperature
Selective Cooling
QST Process

QST Bank

Finishing stand

QST Bank entry
850 °C

Quenching

Self Tempering
600 °C
QST Process

Self-tempering 600°C

850°C

QST Quenching
Rolled Sections - Grades

- 235 MPa = S235 JR, St 37-2, Fe 360, A36 (245 MPa), Q235
- 275 MPa = S275 JR, 43B, 43C
- 355 MPa = S355 JR, 50B, 50C, 50D, A572/50, A992/50, Q345
- HISTAR 355, A913 / 50 (345 MPa)
- HISTAR 460, A913 / 65 (450 MPa)
- HISTAR 355 TZK, OS (for offshore – low temp.)
- HISTAR 460 TZK, OS (for offshore – low temp.)
Properties of HISTAR Steels
Production of hot-rolled H-beams

Comparison of rolling processes

- Hot rolling
- TM rolling
- QST treatment

Temperature (°C)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>GRAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>800</td>
<td></td>
</tr>
<tr>
<td>600</td>
<td></td>
</tr>
</tbody>
</table>

- recrystallised austenite
- Non-recrystallised austenite
- Ferrite + Austenite
- Ferrite + Perlite
- Bainite
- Martensite

Time

DEFORMATION
Stress – Strain curve

A913 Grade 450

flange thickness = 0.88” [22.5 mm]

Fy = 68.5 ksi [473 MPa]

Fu = 86.4 ksi [596 MPa]

A200 = 22.0%, (A5d = 25.9%)
Charpy V Notch impact test (CVN)
A913 - HISTAR: Toughness

Temperature for toughness Guarantee (°C) = Transition temperature
ASTM A913 : Ductility

Bent test at 180°
Radius = 0
HISTAR : HD 400 x 1086 kg/m in A913/gr. 450

No Preheat!
Bent test after welding: A913/gr. 450

SMAW  
E = 12 kJ/cm

FCAW  
E = 8 kJ/cm

SAW  
E = 35 kJ/cm

SMAW  
E = 12 kJ/cm

FCAW  
E = 8 kJ/cm

SAW  
E = 35 kJ/cm

SAW  
E = 50 kJ/cm
HISTAR / A913 : Weldability

\[ CE(\%) = C(\%) + \frac{Mn(\%)}{6} + \frac{(Cr + Mo + V)(\%)}{5} + \frac{(Cu + Ni)(\%)}{15} \]

Preheating °C

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130
70
50
> 0

CE (%)

conventional grades

HISTAR A913

Re (MPa)

140 (mm)
Seismic Design

The typical connection used prior to 1994. Severe stress concentrations inherent in its configuration were not considered in the design.

Fractures Commonly initiate at the welded joint of the beam bottom flange to column.
Seismic Design

Desired plastic frame behavior

Undeformed frame

Deformed frame shape

Plastic Hinges

drift angle - θ

L

L’
Seismic Design

Many steel moment-frame buildings were damaged in the 1995 Kobe earthquake.
Seismic Design
ASTM A913: Through-thickness
ASTM A913: Through-thickness

- Column flange
  - A913/gr. 450
  - 450 MPa

- Beam flange
  - A913
  - 345 MPa

T1, T2, T3, T4
Strong Column - Weak Beam Concept enhanced by Reduced Beam Section (RBS)

199 Fremont, San Francisco

Column: A913 Grade 450
Beam: Grade 345

Courtesy KMD architects

Courtesy EQE International
Comparison of Standards

<table>
<thead>
<tr>
<th></th>
<th>ASTM</th>
<th>A913/Gr. 450</th>
<th>A913/Gr.345</th>
<th>A572(A992)/Gr.345</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Equiv. max.</td>
<td>0.43 %</td>
<td>0.38%</td>
<td>0.47 % (0.45 %)</td>
<td></td>
</tr>
<tr>
<td>Carbon max.</td>
<td>0.14 %</td>
<td>0.12%</td>
<td>0.23 %</td>
<td></td>
</tr>
<tr>
<td>Sulfur max.</td>
<td>0.030 %</td>
<td>0.030 %</td>
<td>0.045 %</td>
<td></td>
</tr>
<tr>
<td>Copper max.</td>
<td>0.35 %</td>
<td>0.45 %</td>
<td>0.60 %</td>
<td></td>
</tr>
<tr>
<td>CVN min.</td>
<td>54 J @ 21°C</td>
<td>54 J @ 21°C</td>
<td>No min.</td>
<td></td>
</tr>
</tbody>
</table>

30 % higher yield strength
All at the same cost
HISTAR and the Codes

- Tailor-Made beams ASTM A6 (1985)
- ASTM A913 - Euronorms (1993)
- AISC - ASD and LRFD (1996)
- AWS D1.1 -- Welding Code (1996)
- NYC - Building Code (2001)
- Approved in China (2004)
1. Production of rolled sections
2. Tailor - Made Beams
3. HISTAR
4. Applications
ArcelorMittal loves NY

- Sloan Kettering Hosp.
- 731 Lexington
- Citicorp
- Mt. Sinai Hosp.
- Time Warner “Lipstick”
- Hearst
- 599 Lex. Worldwide Plaza
- 1745 B’way (Random H.)
- 750 Seventh Ave
- Swiss Bank - Saks
- 1585 Broadway
- Morgan Stanley
- 450 Lexington
- New York Times
- Loews Theater, 42nd St.
- Hilton, 42nd St.
- Times Square 4 (Conde Nast)
- 300 Madison (CIBC)
- Times Sq. 5 (Ernst & Young)
- 383 Madison (Bear S.)
- 420 Fifth Ave
- NYU Palladium
- Hutton Plaza
- Shearson Lehman
- St. Luke’s Hospital
- Baruch College
- 60 & 75 Wall Street
- World Financial C.
- WTC 7 Reconstr.

New York Skyline
Freedom Tower – New York
Architect: Skidmore, Owings & Merrill
Developer: Silverstein Properties
Total building height: 541m
~250,000m² office floor

First delivery of 850t of HISTAR jumbo sections for the structure of the basement
(December 2006)
Typical applications
Skyscrapers

San Francisco skyline

Los Angeles
Bunker Hill Area

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Emirate Towers - Dubai
Gravity columns

Short buckling lengths

HISTAR 460
concrete cores

columns in

HISTAR 450

Brussels

Barcelona
Shanghai World Financial Center
ASTM A913
Applications

- Buildings
- **Offshore platforms**
- Plants
- Parking garages
- Bridges
- Trusses
Conversion from built-up sections to rolled sections

Lanxi Power Plant - China
Applications

- Buildings
- Offshore platforms
- Plants
- Parking garages
- Bridges
- Trusses
Long span: no internal columns
Applications

- Buildings
- Offshore platforms
- Plants
- Parking garages
- Bridges
- Trusses
Istanbul
## Economical aspects of steel structures

Advantages of high strength steels in steel-concrete composite construction

<table>
<thead>
<tr>
<th>Type of construction</th>
<th>non-composite</th>
<th>composite</th>
<th>composite</th>
<th>composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel grade</td>
<td>S 235</td>
<td>S 235</td>
<td>S 355</td>
<td>S 460</td>
</tr>
<tr>
<td>Section</td>
<td>HE 650 A</td>
<td>HE 550 A</td>
<td>IPE 550</td>
<td>IPE 500</td>
</tr>
<tr>
<td>Reduction in weight of steel</td>
<td>-</td>
<td>13 %</td>
<td>44 %</td>
<td>52 %</td>
</tr>
</tbody>
</table>
108 m

3000 tons ASTM A913/gr. 450
35 % lighter than 345 MPa Boeing 777 in Seattle
Typical applications
Trusses
Typical applications
Trusses
Potential savings A913/gr. 450 → gr. 245

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Material Cost Savings

10 to 30%

10 to 50%

Fabrication Savings

7 to 30%

Miscellaneous Savings:
- Erection
- Transport
- Foundations

0 to 15%

Total Savings

15 to 35%

(Material) Weight Savings

0 to 15%
Thank you for your attention!

http://www.arcelormittal.com/sections