NORTHRIDGE 20
SYMPOSIUM

Structural Steel: Materials and Inspection

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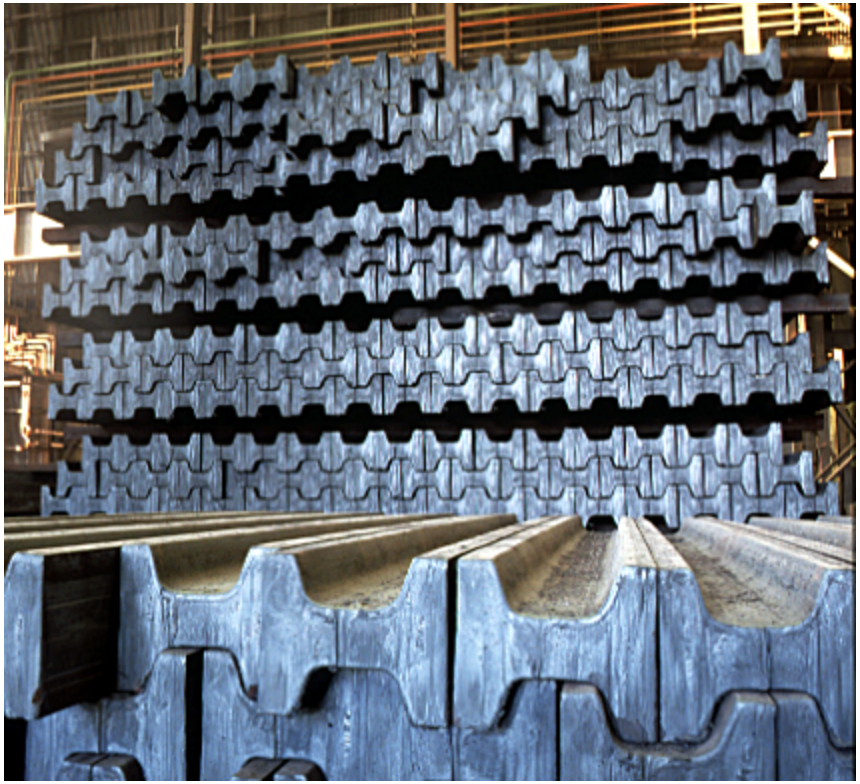
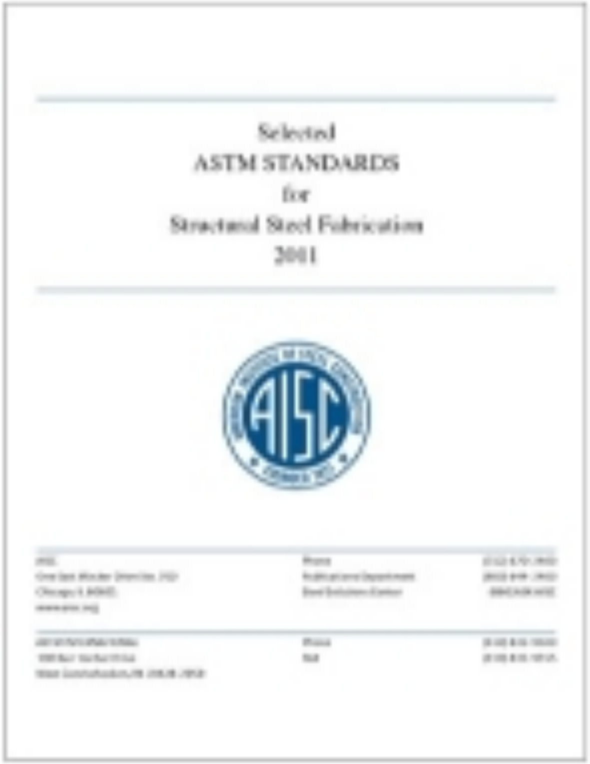
Structural Steel: Materials
Standards and Processes





Selected
ASTM STANDARDS
for
Structural Steel Fabrication
2001

Structural Steel: Materials
Standards and Processes

There were two areas of change taking effect around 1994 and after:

1. People responding to findings from the earthquake developed changes in requirements through code and specification revisions

2. The prevalence of Scrap-based Electric Arc Furnace/ Continuous Cast process was substantial and recognized.

Both of these elements had an impact on the materials we use.

Structural Steel: Materials
Standards

Requirements for structural steel materials are described in the ASTM standards

ASTM A6 describes general requirements for structural shapes and plate including dimensions, tolerances and testing requirements.

- A change in A6 moved the tensile test specimen from the web to the flange resulting in measures of yield and tensile strength in the location of most interest to the engineer. This had the effect of raising the lower strength members by about 5%

Structural Steel: Materials
Standards

In 1994 ASTM published A913. This standard described a new process called Quenching and Self-tempering. A new way to achieve strength with less chemical strengtheners and resulting in a steel with lower welding preheat requirements.

Domestic industry recognized that EAF Continuous Cast shapes were the prevalent and preferred product and that seismic design demanded some new requirements.

Development of A992 was started

ASTM A992 / A992M

Designation: A 992/A 992M – 98$^{\epsilon 1}$

Standard Specification for Steel for Structural Shapes For Use in Building Framing[1]

This standard is issued under the fixed designation A 992/A 992M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ϵ^1 NOTE—The designation of this standard was editorially corrected in December 1998.

1. Scope

1.1 This specification covers "W" shapes (rolled wide flange shapes) intended for use in building framing.

1.2 Supplementary requirements are provided for use where additional testing or additional restrictions are required by the purchaser. Such requirements apply only when specified in the purchase order.

1.3 When the steel is to be welded, a welding procedure suitable for the grade of steel and intended use or service is to be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.4 It is recommended that the purchaser consider specifying supplementary requirements such as fine austenitic grain size and Charpy V-notch impact requirements when considerations such as dynamic loads, low temperature service or welding details demand. For Group 4 and 5 shapes for use in applications subject to tension loads, it is recommended that the purchaser consider specifying Charpy V-notch impact requirements.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system is to be used independently of the other without combining values in any way.

1.6 The text of this specification contains notes or footnotes, or both, that provide explanatory material; such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

2. Referenced Documents

2.1 *ASTM Standards:*

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 673/A 673M Specification for Sampling Procedure for Impact Testing of Structural Steel[2]

E 112 Test Methods for Determining Average Grain Size[3]

3. General Requirements For Delivery

3.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M for the ordered material, unless a conflict exists, in which case this specification shall prevail.

4. Materials and Manufacture

4.1 The steel shall be made by one of the following processes: open-hearth, basic-oxygen, or electric-furnace. Additional refining, by electroslag remelting (ESR), vacuum-arc remelting (VAR), or ladle metallurgy furnace (LMF) is permitted.

4.2 The steel shall be killed. Killed steel is confirmed by a statement of ***killed steel*** on the test report or by reporting strong deoxidizers, such as 0.10 min % Si or 0.015 min % A1.

4.3 The steel shall be made to a practice producing nitrogen not greater than 0.012 %; or the steel shall be made to a practice producing nitrogen not greater than 0.015 % and one or more nitrogen-binding elements shall be added.

5. Chemical Composition

5.1 The heat analysis shall conform to the requirements in Table 1.

5.2 In addition to the elements listed in Table 1, test reports shall include, for information, the chemical analysis for tin. Where the amount of tin is less than 0.02 %, it shall be permissible for the analysis to be reported as "< 0.02 %".

5.3 The steel shall conform on product analysis to the requirements prescribed in Table 1, subject to the product analysis tolerances in Specification A 6/A 6M.

5.4 The maximum permissible carbon equivalent value shall be 0.47 % for shapes in Groups 4 and 5, and 0.45 % in other shapes. The carbon equivalent value shall be based on heat analysis. The required chemical analysis as well as the carbon equivalent shall be reported. The carbon equivalent shall be calculated using the following formula:

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

Current edition approved June 10, 1998. Published August 1998.

[2] *Annual Book of ASTM Standards*, Vol 01.04.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

Structural Steel: Materials
Standards

Sadly, Dr G Haaijer passed away as the key elements of the new standard were being considered. Dr Haaijer's insight and experience have been missed sorely through the development of A992 and many of the other provisions discussed in this symposium.

Structural Steel: Materials
Standards

A992 was adopted in 1998. It brought a number of changes:

- Maximum yield strength (the maximum yield was set at the minimum tensile strength to help meet the strong column weak beam concept in seismic design in a local sense)
- Y/T was limited to 0.85 as a second measure of ductility

Structural Steel: Materials
Standards

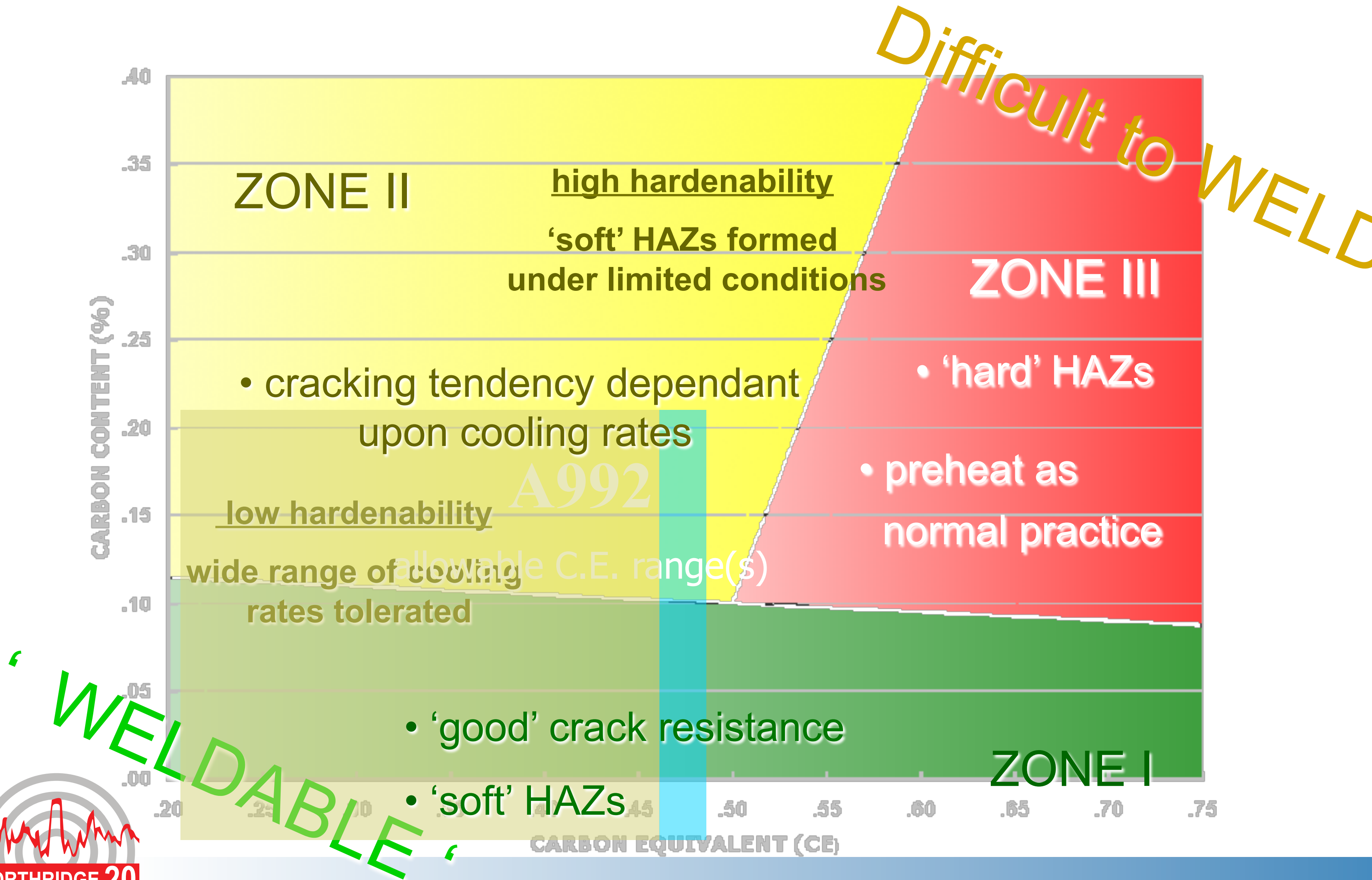
Weldability properties took a new place in standards:

- Carbon Equivalent was limited
- Maximum limits were applied to other elements (silicon, copper, nickel, chromium, molybdenum)

Weldabilty

Zone Classification of Steels

Steel Dynamics, Inc.™ Structural & Rail Mill



$CE_{(IIW)} = C + {}^{(Mn+Si)}/_{6} + {}^{(Cr+Mo+V)}/_{5} + {}^{(Ni+Cu)}/_{15}$

Structural Steel: Materials
Standards

Subsequent to 1994

- Domestic producers, the prevalent producers for US construction, expanded the range of product rolled to provide heavy and deep shapes
- Studies have been conducted:
  - Summarizing plate and shape properties
  - Producer Tensile test repeatability
  - Toughness

Structural Steel: Materials
Standards

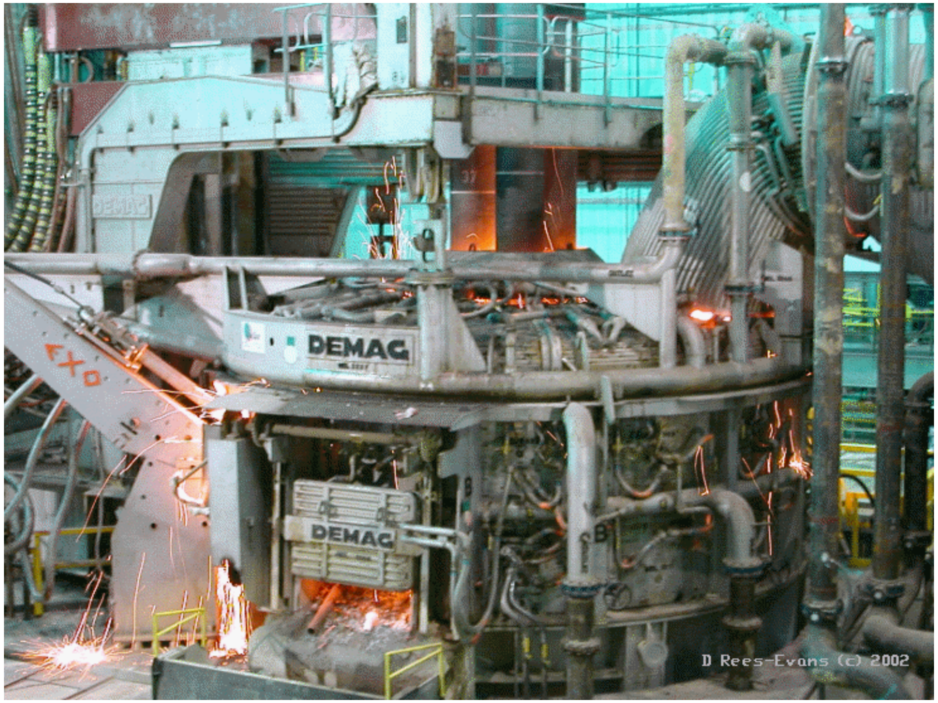
Just one year ago, in April 2013, ASTM published A1085 for HSS

Like A992 it has a maximum yield to help seismic designers who use the *expected yield* and design adjacent frame members to the capacity of the brace.

It also has controls on dimensional tolerances and toughness

Structural Steel: Materials
Properties

A992 was written in part to reflect the prevalence of the EAF continuous cast product being provided. But there are other property changes we are pleased to be able to tell you about.



Structural Steel: Materials

Electric Arc Furnace

Structural Steel: Materials
Properties

The Electric Arc Furnace (EAF) / Continuous Cast process is remarkable! (and Demanding)

Imagine pouring any liquid into a bottomless mold and achieving a consistent shape.

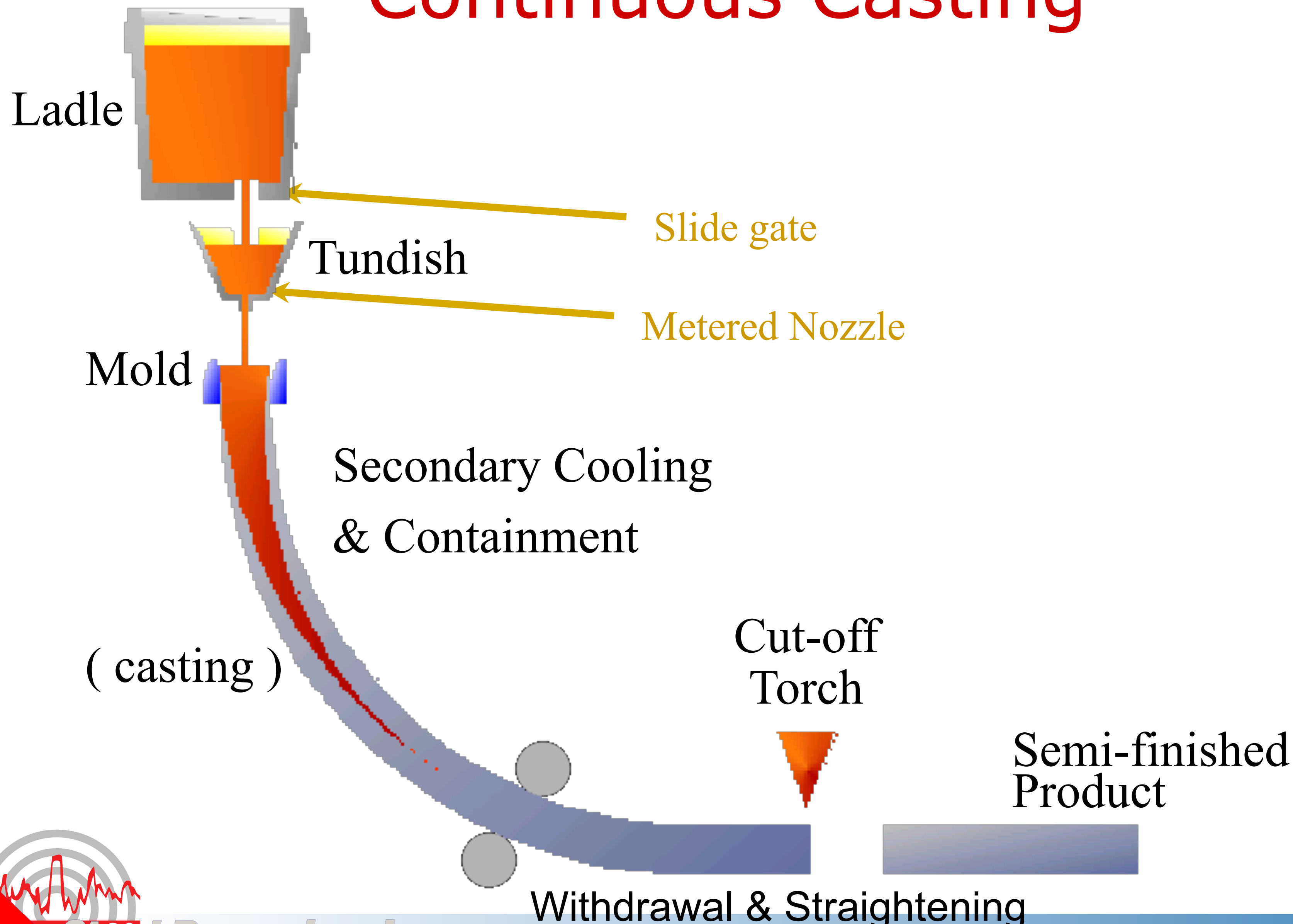
Now do it with tons of material at 490 lbs per cubic foot.

Now cast it hot enough to flow in the mold and cool it in the mold so that it holds its shape, but not so much that it will not turn to a horizontal position at the bottom of caster.

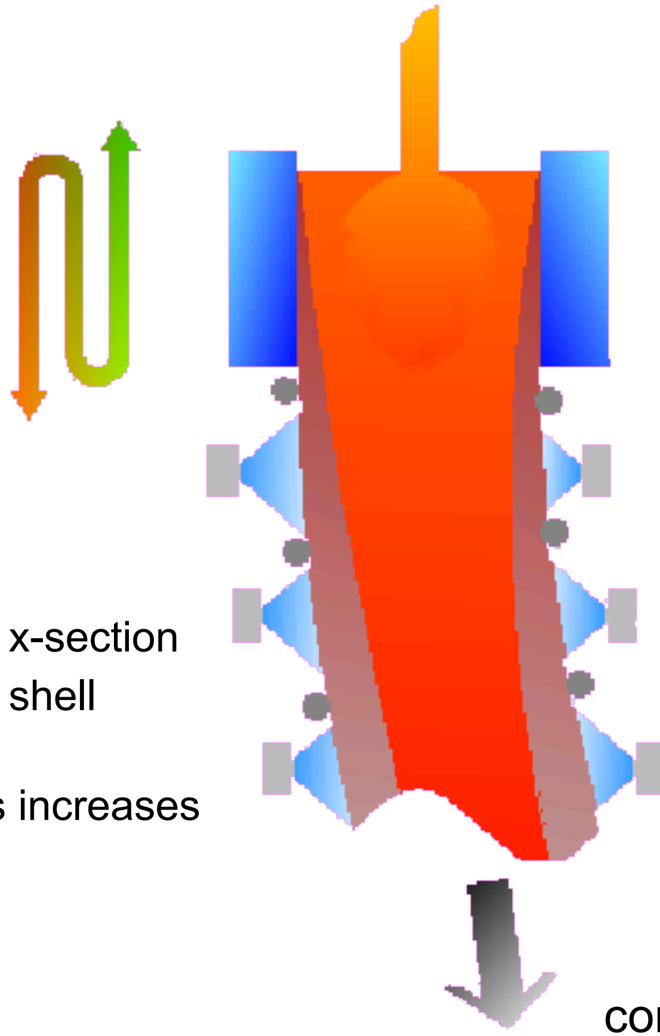
Structural Steel: Materials
Properties

That process can be performed only when producers achieve properties and a level of consistency in the molten steel that results in quality fabricators and designers benefit from.

Continuous Casting



Continuous Casting Mold



- Mold
  - desired x-sectional shape
  - water cooled - copper
  - oscillates
  - powder / oil lubrication

- Cast Shell
  - shape of mold x-section
  - thin quenched shell
  - liquid core
  - shell thickness increases with depth

- Spray & Containment
  - secondary cooling
  - maintains shape

continuous withdrawal

Structural Steel: Materials
Properties

Rolling the final shape is similarly difficult and has been improved continuously.

Structural Steel: Materials
Properties

Results of this process include:

1. All steel from the continuous cast process is killed (internal soundness is better)
2. Temperature through the process is controlled more strictly (better grain structure)
3. Casting ‘near net shapes’ cools faster (better grain structure, less segregation)
4. EAF/ CC steel has much lower carbon (improved weldability)
5. The shape and form of inclusions are controlled (improved through thickness properties)

Structural Steel: Materials
Properties

Rolling the final shape requires heating it to make the material formable, reducing the thickness of the cast shape by a factor of at least 3 and in that process it grows in length from about 40 feet to as much as 400 feet.

Automation of the rolling has not only helped keep the industry competitive, it provides good quality. One major producer reports quality issues at less than 0.1%.

Structural Steel: Materials
Properties

And

It is recycled material (Sustainable)

Structural Steel: Materials

Standards and Properties

Structural steel produced in 2014 offers many advantages over those furnished in 1994.

- Advantages described in standards and
- Advantages demanded by the production process.

Structural Steel: Inspection
Codes and Practices

There was a plan to require a QAP developed for each structural project.

Concepts related to that requirement varied.

Steel stakeholders agreed that one good plan could be implemented more effectively and efficiently than varying plans developed for each project. They also felt a committee of leading fabricators, inspectors and engineers were highly qualified to write this plan. With those thoughts in mind, AISC 341 Chapter J was drafted.

Structural Steel: Inspection
Codes and Practices

Similar to the way materials have changed in standard requirements and production, Inspection has changed both in Code requirements and practice.

- Clarification of inspection requirements
- New Inspection requirements
- Inspection of new fabrication requirements

Structural Steel: Inspection
Codes and Practices

The key documents containing changes in inspection requirements are

AISC 341 Seismic Provisions Chapter J

AWS D1.8 Seismic Supplement Clause 7

Structural Steel: Inspection

Codes and Practices

In 1994 IBC required UT of beam to column joints and confirmation of materials and compliance with AISC and AWS by reference.

Structural Steel: Inspection
Codes and Practices

In 2014 :

AISC Seismic Provisions (341) Chapter J adds inspection requirements and delineates inspection tasks that were considered a part of previous requirements and it adds a measure of task frequencies.

AWS Seismic Supplement D1.8 adds inspection requirements

Structural Steel: Inspection
Codes and Practices

There are more requirements in these documents than can be discussed in this presentation but some significant items include:

AISC 341

QA and QC Documentation Requirements (Records submitted and available)

NDT (K-area, CJP, lamellar tears, thick copes and access holes, repair and tab removal sites)

Ultrasonic Testing (UT)

Structural Steel: Inspection
Codes and Practices

AWS D1.8:

QA Inspector Qualifications (AWS B5, QC1 or CB)

NDT Technician Qualifications (Annex E tests on mock-ups)

UT procedures documented and qualified on mock-ups (Annex S3)

Seismic Welder Mock-up

Structural Steel: Inspection

Codes and Practices

The specification element that may represent a significant change in practice is the delineation of inspection tasks in Tables J6 & J7. While the tasks in these tables are not new, these clear lists drive a change in the customary practice.

QA/QC Checklist

SPLICE ONLY 3453A

Table 6-2 Process and Visual Welding Inspection Tasks

Process and Visual Welding Inspection Category:		1				2				3			
		Inspector											
Inspection Tasks (A 04-17-04 BD)	Welder	QC		QA		QC		QA		QC		QA	
		H	O	H	O	H	O	H	O	H	O	H	O
Inspection Prior to Welding													
Proper WPS selected for joint detail A B9	✓	✓ DR		✓		✓			✓		✓		✓
Proper welding materials selected A B9	✓	✓ DR		✓	CLA	✓			✓		✓		✓
WPS settings (voltage, polarity, current, wire feed speed) on welding equipment verified A B9	✓	✓ DR			✓ CLA		✓		✓		✓		✓
Shielding gas type (if used) verified A B9	✓	✓ DR			✓		✓		✓		✓		✓
Shielding gas flow rate setting verified A B9	✓	✓ DR			✓		✓		✓		✓		✓
Fit of backing bar (if used) acceptable A B9	✓	✓ NA			✓		✓		✓		✓		✓
Measure root opening A B9	✓		DR		✓		✓		✓		✓		✓
Measure groove angle A B9	✓		DR		✓		✓		✓		✓		✓
Verify above dimensions within joint tolerance and WPS tolerance A B9	✓	✓ DR			✓		✓		✓		✓		✓
Mark root edge location on beam flange for UT inspection (if required) A B9	✓	✓ NA			✓		✓		✓		✓		✓
Condition of steel surface acceptable A B9	✓	✓ DR			CLA		✓		✓		✓		✓
Existing tack welds clean and of adequate quality A B9	✓	✓ DR			✓		✓		✓		✓		✓
Wind velocity within limits A B9	✓		✓ DR		CLA		✓		✓		✓		✓
Weld joint surfaces free of discontinuities A B9	✓		✓ DR		CLA		✓		✓		✓		✓
Minimum preheat required applied and verified A B9	✓		✓ DR		CLA		✓		✓		✓		✓
Maximum preheat verified A B9	✓		DR		CLA		✓		✓		✓		✓
Observation of welder's inspection A B9	✓		DR		CLA		✓		✓		✓		✓
Observation of QC inspection					CLA		✓		✓				✓

See Legend and Notes at the end of the table.

Structural Steel: Inspection

Codes and Practices

Structural steel now has a well defined QC/QA plan that, if followed, provides a superior level of assurance that the structure that was designed is the structure that was built.

We ask that you specify and rely on that plan and avoid modifications.

Structural Steel: Inspection
Codes and Practices

Thanks to

• Mike Engestrom	NYS
• Doug Rees-Evans	SDI
• Mike Mayes	Mayes Testing