There's always a solution in steel.

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Course Description

The History of the AISC Specification
1923-2010
January 22, 2016

The American Institute of Steel Construction (AISC) was created in 1921, and the first edition of an iconic design standard, the *Specification for Structural Steel Buildings* was issued in 1923. This first edition was a modest 13 pages long, but it was a powerful instrument in unifying structural steel design practice in the United States. Since then, the document has been greatly expanded to include new research and practice, and it has been a model for equivalent standards in many other countries. This seminar will present not only the evolution of the technical aspects of the *Specification*, but also the ideas behind the rules, and the personalities of the engineering leaders who helped make it into the great helper of structural engineers. The author, Ted Galambos, has been involved with many aspects in the history of this document since he started graduate research on the behavior of steel structures in 1956 at Lehigh University.

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Learning Objectives

- Become familiar with the history of the AISC *Specification*
- Understand the evolution of column formulas in the AISC *Specification*
- Understand the evolution of lateral-torsional buckling rules in the AISC *Specification*
- Become familiar with motivations for *Specification* changes including examples of research initiated practice and industry initiated practice

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There's always a solution in steel.

The History of the AISC Specification 1923-2010

Presented by
Theodore Galambos, Ph.D., P.E.
University of Minnesota
Minneapolis, MN

structural STEEL

THE HISTORY OF THE AISC SPECIFICATION 1923 - 2010

BY

TED GALAMBOS

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THE REASON FOR THIS TALK

- *IN 2021 AISC WILL HAVE SERVED THE STEEL FABRICATION INDUSTRY FOR 100 YEARS*
- *IN 2023 THE AISC SPECIFICATION, THE STRONG ARM OF THIS SERVICE, WILL ALSO BECOME A CENTENARIAN*
- *TED GALAMBOS, AMONG A FEW OTHERS STILL LIVING, HAS BEEN INVOLVED IN THE LIFE OF THIS DOCUMENT FOR MOST OF THE SECOND HALF OF ITS EXISTENCE*
- *SO, IT IS TIME TO REMEMBER BEFORE TED FORGETS*

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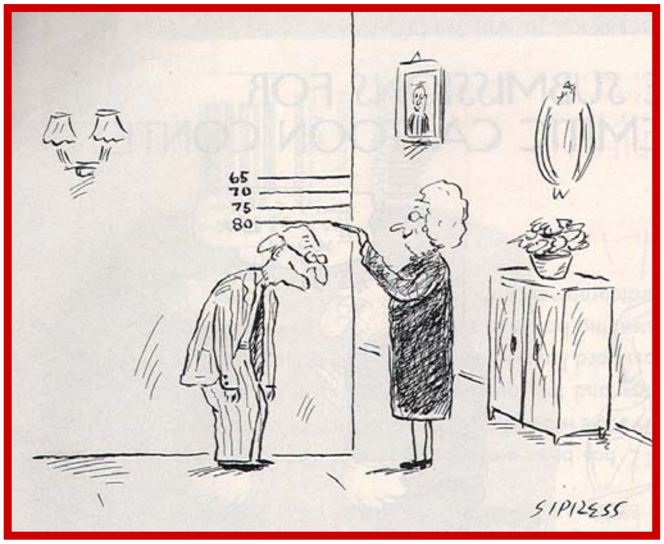

Cartoon from New Yorker magazine

11

Lynn Beedle, Ted, Fritz Lab

My first Day at Fritz Lab, LEHIGH

SEP. 1 1956

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"For those of you who don't know **Ted Galambos**
he's our institutional memory."

Cartoon from the New Yorker Magazine

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Why was it important to approve a standard for the design of steel structures in 1923?

It was such an important step that the Secretary of the Commerce of the time, Herbert Hoover (an engineer and later a president of the US), sent a commendatory letter to the AISC.

At the inaugural meeting of the AISC, one of the list of objectives to be achieved was:

"The establishment of a single code authority that would be recognized by building code authorities and designers to eliminate the confusion that then existed in the construction industry, caused by the numerous and different manuals each containing proprietary information."

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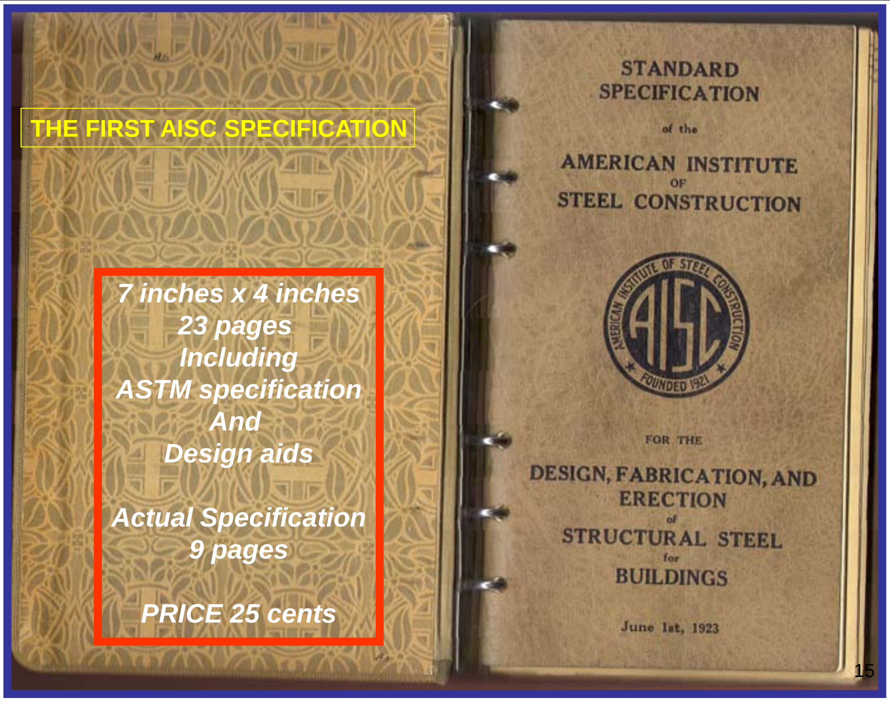


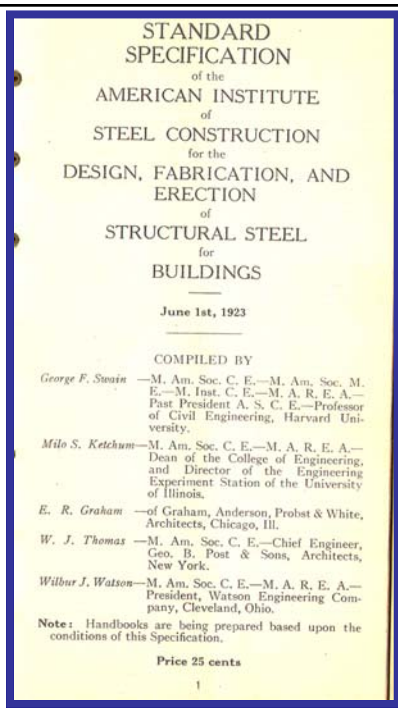
THE FIRST AISC SPECIFICATION

7 inches x 4 inches
23 pages
Including
ASTM specification
And
Design aids

Actual Specification
9 pages

PRICE 25 cents

15



STANDARD
SPECIFICATION
of the
AMERICAN INSTITUTE
of
STEEL CONSTRUCTION
for the
DESIGN, FABRICATION, AND
ERECTION
of
STRUCTURAL STEEL
for
BUILDINGS

June 1st, 1923

COMPILED BY

George F. Swain —M. Am. Soc. C. E.—M. Am. Soc. M. E.—M. Inst. C. E.—M. A. R. E. A.—Past President A. S. C. E.—Professor of Civil Engineering, Harvard University.

Milo S. Ketchum—M. Am. Soc. C. E.—M. A. R. E. A.—Dean of the College of Engineering, and Director of the Engineering Experiment Station of the University of Illinois.

E. R. Graham —of Graham, Anderson, Probst & White, Architects, Chicago, Ill.

W. J. Thomas —M. Am. Soc. C. E.—Chief Engineer, Geo. B. Post & Sons, Architects, New York.

Wilbur J. Watson—M. Am. Soc. C. E.—M. A. R. E. A.—President, Watson Engineering Company, Cleveland, Ohio.

Note: Handbooks are being prepared based upon the conditions of this Specification.

Price 25 cents

1

THE AUTHORS:

Two professors

George F. Swain, HARVARD U.

Milo S. Ketchum, U of ILLINOIS

Two structural engineers

W. J. Thomas, NY City

Wilbur J. Watson, Cleveland

One architect

E. R. Graham, Chicago

Note: All previous editions of the AISC Specifications are available on the AISC Website as free downloads for members

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THE 1923 AISC SPECIFICATION IS A TRUE PERFORMANCE-BASED SPECIFICATION!

- ***"To obtain a satisfactory structure, the following major requirements must be fulfilled"***
- ***(a) "The material used must be suitable, of uniform quality, and without defects affecting the strength or service of the structure"***
- ***(e) "The computations and the design must be properly made so that the unit stresses specified shall not be exceeded, and the structure and its details shall possess the requisite strength and rigidity"***

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MAJOR HEADINGS IN THE 1923 AISC SPECIFICATION

- ***4. Loading***
- ***5. Allowable stresses***
- ***7. Beams and girders***
- ***9. Eccentric Loading***
- ***10. Combined stresses***
- ***13. Rivets and bolts***
- ***15. Connections***
- ***16. Lattice***
- ***18. Minimum thickness***
- ***22. Erection***
- ***23. Inspection***

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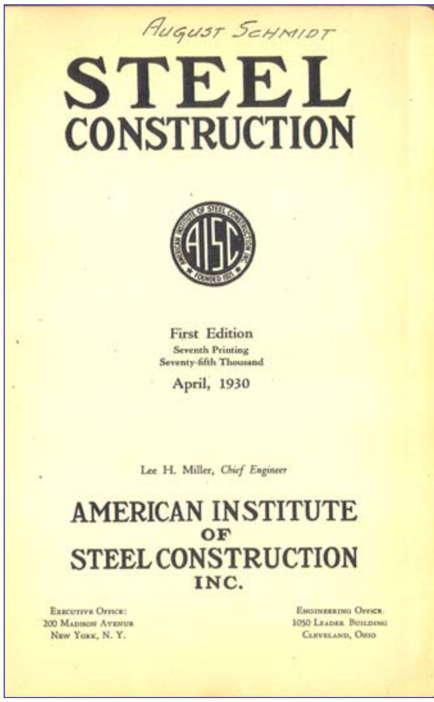

THE FIRST EDITION OF THE AISC MANUAL

Part IV is almost a text-book
"EXPLANATION OF
AISC SPECIFICATION FORMULAE"

Beams
Web shear and stiffeners
Laterally unsupported flanges
Columns
Rivet stresses

PRICE: $2.00
476 pages long

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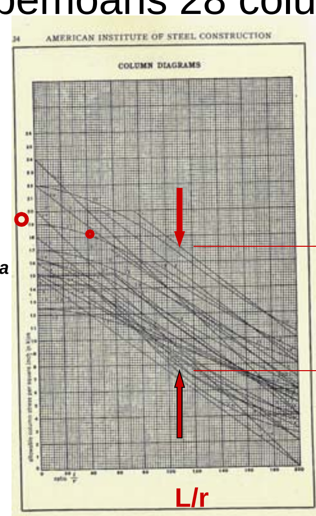
THE 1923 COLUMN FORMULA DILEMMA

- The AISC MANUAL bemoans 28 column formulas in use

Scatter of column curves



F_a

10 ksi

L/r

"The diagrams clearly illustrate that the basic unit stress is not a consistent index of the so-called factor of safety" (p.225)

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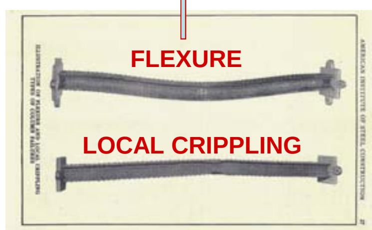
THE 1923 AISC COLUMN FORMULA (RANKINE FORMULA)

$$F_c = \frac{18,000}{1+\frac{1}{18,000}\left(\frac{L}{r}\right)^2} \le 15,000\ psi$$



LOCAL CRIPPLING

CONTROLS

Up to L/r = 60

21

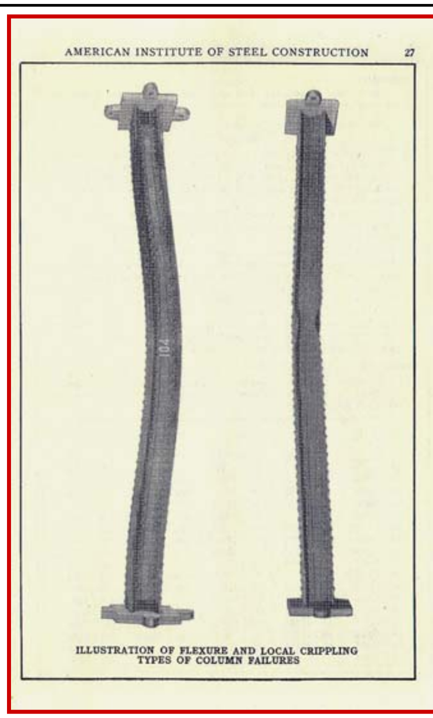


FIGURE FROM THE FIRST AISC MANUAL

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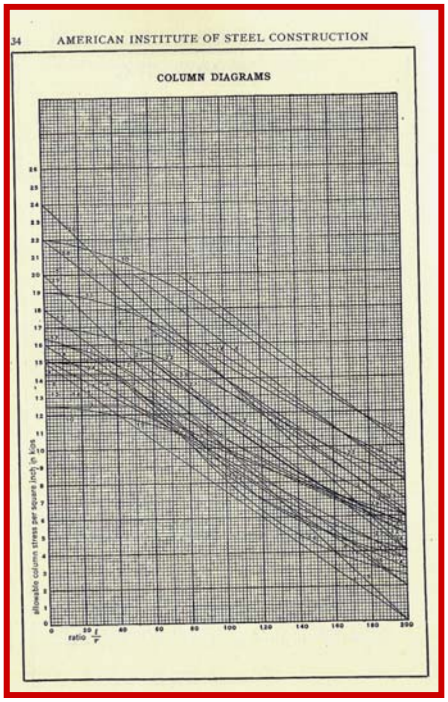
FIGURE FROM THE FIRST AISC MANUAL



A HERD OF COLUMN FORMULAS

23

THE MAJOR YEARS OF THE "ASD" EDITIONS

- ***1923*** — ***The beginning***
- ***1936***
- ***1949***
- ***1961/1963*** — ***Radical change***
- ***1969***
- ***1978***
- ***1989*** — ***The end of the "stress era"***
- ***1986*** — ***The beginning of the "strength era"***

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The growth of knowledge, I hope

Year of Adoption	Specification Pages	Commentary Pages	Committee Members
1923	11	0	5
1936	19	0	?
1949	30	0	?
1963	44	46	26
1969	103	44	36
1978	93	68	43
1989	83	68	43
1986	91	66	42
1993	110	92	46
1999	124	113	46
2005	196	231	40
2010	329	311	46

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STEEL FOR AISC SPECIFICATIONS

Last Year of Adoption	*Serial Designation*	*Tensile Strength, F_u*	*Yield point*
1929	ASTM A9-29	55-65 ksi	$F_u/2$ <=30ksi
1936	ASTM A9-36	60-72 ksi	$F_u/2$ <=33ksi
1946	ASTM A7-46	60-72 ksi	$F_u/2$ <=33ksi

In 1963 there were choices of available steels: ASTM A7, A373, A36, A440, A441, A242!!!!

F_y from 33 to 50 ksi !!!!

WOW!

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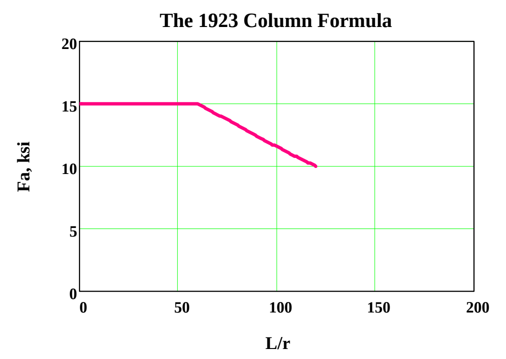
EVOLUTION OF COLUMN FORMULAS

$$F_a = \frac{18ksi}{1+\frac{1}{18000}\left(\frac{L}{r}\right)^2} \le 15ksi$$

1923 - 1936



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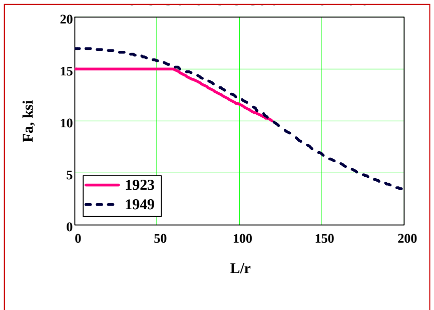
EVOLUTION OF COLUMN FORMULAS

$$F_a = 17 - 0.485\times 10^{-3}\left(\frac{L}{r}\right)^2 \quad for\ 0 \le \frac{L}{r} \le 120$$

$$F_a = \frac{18ksi}{1+\frac{1}{18000}\left(\frac{L}{r}\right)^2}\left[1.6 - 0.005\left(\frac{L}{r}\right)\right] \quad for\ 120 < \frac{L}{r} \le 200$$

1936 -1961



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EVOLUTION OF COLUMN FORMULAS

$$C_c = \sqrt{\frac{2\pi^2 E}{F_y}}$$

$$FS = \left\{ \frac{5}{3} + \frac{3}{8}\left[\frac{kL/r}{C_c}\right] - \frac{1}{8}\left[\frac{kL/r}{C_c}\right]^3 \right\} \quad for \quad \left[\frac{kL/r}{C_c}\right] \le 1$$

$$F_a = \frac{F_y}{FS}\left[1 - 0.5\left[\frac{kL/r}{C_c}\right]^2\right] \quad for \quad \left[\frac{kL/r}{C_c}\right] \le 1$$

$$F_a = \frac{12}{23}\frac{\pi^2 E}{(kL/r)^2} \quad for \;\; C_c < kL/r \le 200$$

1961 - 1989

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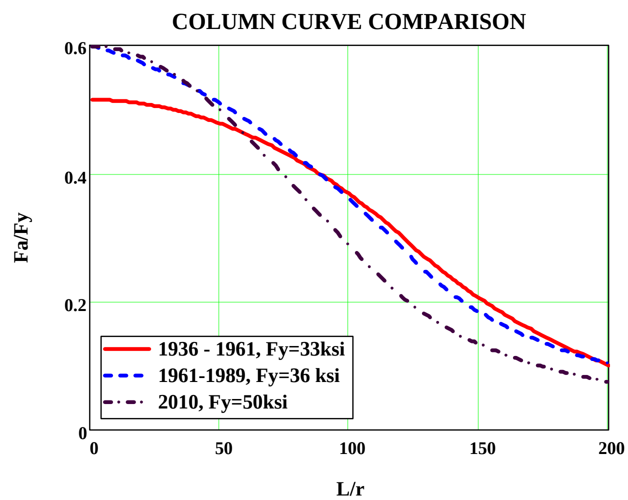
EVOLUTION OF COLUMN FORMULAS



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EVOLUTION OF LATERAL-TORSIONAL BUCKLING RULES

$$F_b = 18ksi \quad for \quad \frac{L_b}{t_f} \le 15$$

$$F_b = \frac{20ksi}{1 + \frac{1}{2000}\left(\frac{L_b}{t_f}\right)^2} \quad for \ 15 \le \frac{L_b}{t_f} \le 40$$

1923 – 1936 purely empirical

$$F_b = 20ksi \quad for \quad \frac{L_b}{t_f} \le 15$$

$$F_b = \frac{22.5ksi}{1 + \frac{1}{1800}\left(\frac{L_b}{t_f}\right)^2} \quad for \ 15 \le \frac{L_b}{t_f} \le 40$$

1936 – 1949 empirical

$$F_b = 20ksi \quad for \quad \frac{L_b d}{b_f t_f} \le 600$$

$$F_b = \frac{12000}{\frac{L_b d}{b_f t_f}} \ ksi \quad for \quad \frac{L_b d}{b_f t_f} > 600$$

1949 – 1961 a conservative simplified theory

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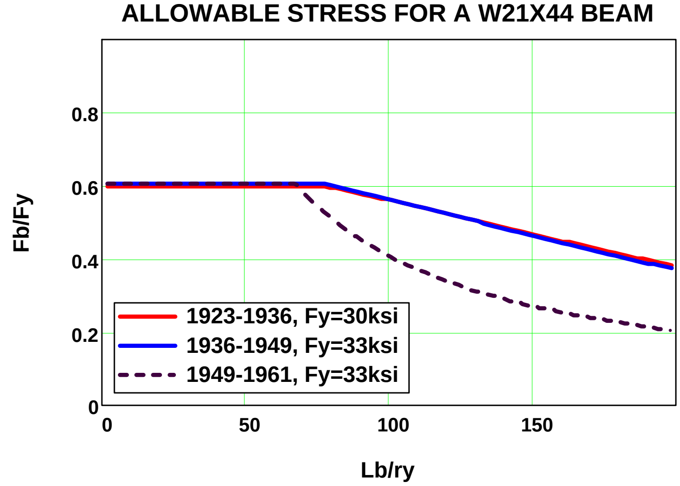
EVOLUTION OF LATERAL-TORSIONAL BUCKLING RULES

ALLOWABLE STRESS FOR A W21X44 BEAM



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EVOLUTION OF LATERAL-TORSIONAL BUCKLING RULES

ELASTIC CRITICAL STRESS BY "EXACT" THEORY (TIMOSHENKO):

$$\sigma_{cr} = \sqrt{\frac{\pi^2 E I_y G J}{S_x^2 L_b^2} + \frac{\pi^4 E^2 I_y C_w}{S_x^2 L_b^4}} = \sqrt{\sigma_V^2 + \sigma_W^2}$$

AFTER SOME ALGEBRA AND ONE SLIGHT APPROXIMATION:

$$\sigma_{cr} = \sqrt{\left(\frac{18900}{L_b d / A_f}\right)^2 + \left(\frac{\pi^2 E}{(L / r_T)^2}\right)^2}$$

$$\sigma_V = \frac{18900}{L_b d / A_f} < \sigma_{cr}$$

$$F_b = 0.6\sigma_V \approx \frac{12000}{Ld / A_f}$$

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EVOLUTION OF LTB RULES, 1961/1963

$$F_b = 0.66F_y \text{ if } L_b \le \frac{76b_f}{\sqrt{F_y}} \text{ and } \frac{20000A_f}{dF_y} \text{ and section is compact}$$

$$F_b = \underline{MAX}\left\{0.6F_y\left[1 - \frac{(L_b / r_T)^2}{2C_c^2 C_b}\right], \frac{12000}{L_b d / A_f}\right\}$$

APPROXIMATION OF $0.6\sigma_W$

$$MAX(\sigma_V, \sigma_W) < \sqrt{\sigma_V^2 + \sigma_W^2}$$

Why were we afraid to take the square root of the sum of two squares???

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EVOLUTION OF LTB RULES, 1969 (A REFINEMENT OF 1963)

$$F_b = 0.66F_y \text{ if } L_b \le \frac{76b_f}{\sqrt{F_y}} \text{ and } \frac{20000A_f}{dF_y} \text{ and section is compact}$$

$$F_{b1} = \left[\frac{2}{3} - \frac{F_y\left(L_b/r_T\right)^2}{1530\times 10^3 C_b}\right]F_y \quad \text{for } \sqrt{\frac{102\times 10^3 C_b}{F_y}} \le \frac{L_b}{r_T} \le \sqrt{\frac{510\times 10^3 C_b}{F_y}}$$

$$F_{b1} = \frac{170\times 10^3 C_b}{\left(L_b/r_T\right)^2} \quad \text{for } \frac{L_b}{r_T} \le \sqrt{\frac{510\times 10^3 C_b}{F_y}}$$

$$F_{b2} = \frac{12\times 10^3 C_b}{L_b d/A_f}$$

$$F_b = MAX\left(F_{b1}, F_{b2}\right) \le 0.6F_y$$

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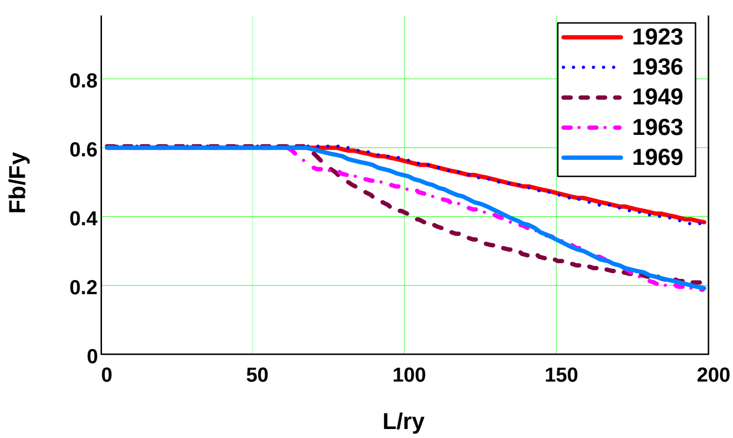
EVOLUTION OF LATERAL-TORSIONAL BUCKLING RULES



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COMBINED STRESS INTERACTION EQUATIONS

$$f_a + f_b \le MIN\left(F_a, F_b\right)$$ 1923

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \le 1$$ 1936, 1849

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \le 1 \quad if \quad \frac{f_a}{F_a} \le 0.15$$ 1961,1963

$$\left\{ \frac{f_a}{F_a} + \frac{C_m f_b}{\left(1 - \frac{f_a}{F_e^{'}}\right) F_b} \le 1 \quad and \quad \frac{f_a}{0.6 F_y} + \frac{f_b}{F_b} \le 1 \right\} \quad if \quad \frac{f_a}{F_a} > 0.15$$

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BIAXIAL BENDING INTERACTION EQUATIONS 1969, 1978, 1989

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \le 1 \quad if \quad \frac{f_a}{F_a} \le 0.15$$

$$\left\{ \begin{array}{l} \frac{f_a}{F_a} + \frac{C_{mx} f_{bx}}{\left(1 - \frac{f_a}{F_{ex}^{'}}\right) F_{bx}} + \frac{C_{my} f_{by}}{\left(1 - \frac{f_a}{F_{ey}^{'}}\right) F_{by}} \le 1 \\ and \quad \frac{f_a}{0.6 F_y} + \frac{f_{bx}}{F_{bx}} + \frac{f_{bx}}{F_{bx}} \le 1 \end{array} \right\} \quad if \quad \frac{f_a}{F_a} > 0.15$$

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WIDTH-THICKNESS LIMITS FOR SLENDER CROSS SECTIONS

1923	b/t=12 limit for beam flanges
1936	b/t=12 limit for angle legs b/t=16 limit for other unstiffened elements h/t=40 limit for stiffened elements
1949	Same limits as in 1936, but if limits are exceeded, lop off the excess in calculating stress
1963	Same criteria for limits as in 1949, but expressed as a function of the square root of F_y.
1969	Stress reduction factors Q_s and effective widths b_e are introduced for unstiffened and stiffened elements

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TOPIC	1923	1936	1949	1963	1969	1978	1989
1/3 increase of stress for wind	x	x	x	x	x	x	x
Fatigue		x	x	x	x	x	x
Plastic Design				x	x	x	x
Moment Redistribution				x	x	x	x
Types of construction				x	x	x	x
Ponding					x	x	x
Vibration					x	x	x
Deflection				x	x	x	x
Web-tapered members						x	x
Hybrid girders					x	x	

SUMMARY OF CHANGES, BY AISC SPECIFICATION EDITION

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TOPIC	1923	1936	1949	1963	1969	1978	1989
Composite beams				x	x	x	x
Encased beams		x	x	x	x	x	x
Incomplete composite action					x	x	x
Metal deck on composite beam						x	x
Welding			x	x	x	x	x
A325 HS bolts			x	x	x	x	x
A490 HS bolts					x	x	x
Friction connections					x	x	x
Combined rivets (bolts) & welds			x	x	x	x	x
Web crippling, etc.			x	x	x	x	x

SUMMARY OF CHANGES, BY AISC SPECIFICATION EDITION

41

TOPIC	1923	1936	1949	1963	1969	1978	1989
Plate girders, riveted	x	x	x				
Plate girders, tension field action				x	x	x	x
Shear-flexure interaction				x	x	x	x
Table of compactness limits							x
Block shear							x
Flexural-torsional buckling							x
$F_b=0.66F_y$ *for beams*				x	x	x	x
Slender plates in columns, Q-factor					x	x	x
Effective length factor for frame stability				x	x	x	x
C_b *factor for beams*				x	x	x	x

SUMMARY OF CHANGES, BY AISC SPECIFICATION EDITION

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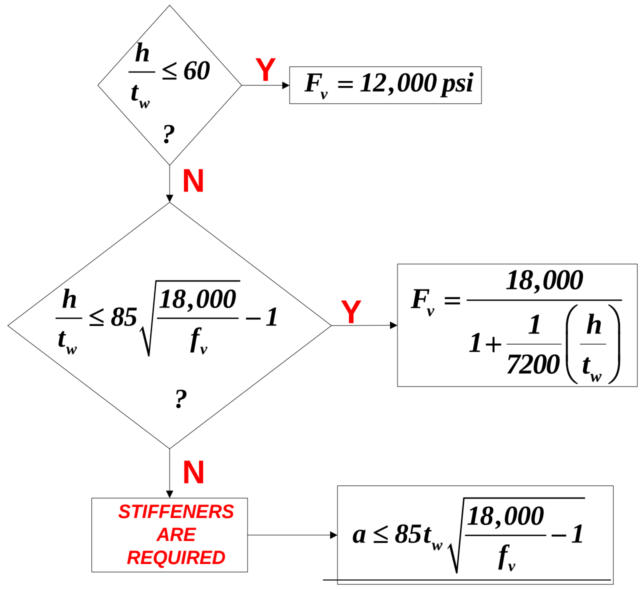
RIVETED PLATE GIRDER WEB DESIGN (1923)



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PARTNERSHIP BETWEEN AISC SPECIFICATIONS AND RESEARCH

A LIST OF AISC SPECIFICATION RESEARCH NEEDS IN 1926:

A satisfactory system of fireproofing
Establishment of equitable fire insurance rates
Quality welding of structural steel
More knowledge about wind bracing
The abatement of noise in riveting
Use of alloy steels in construction
Code body to restrict the heights of buildings
Greater speed of erection to meet demands of increased land prices

L. H. Gillette, (1980), "The First 60 Years, American Institute of Steel Construction, 1921-1980", AISC

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MOTIVATIONS FOR CHANGE

- ***INDUSTRY***
- *Composite design*
- *Stud shear connectors*
- *High strength bolts*
- *Welding*
- *Welded connections*
- *Bolted connections*
- *Many steel grades*
- *High-Performance steels*
- *etc*

- ***ACADEMIA***
- *Plastic design*
- *Stability criteria*
- *Computer methods*
- *Direct design*
- *Bracing rules*
- *Plate girder design*
- *Ponding*
- *Fatigue*
- *Fracture*
- *etc*

TREMENDOUS CHANGES AFTER WWII

45

TWO PATHS

- *INDUSTRY*
  ↓
- *RESEARCH*
  ↓
- *DESIGN STANDARDS*
  ↓
- *PRACTICE*

- *THEORY*
  ↓
- *RESEARCH*
  ↓
- *DESIGN STANDARDS*
  ↓
- *PRACTICE*

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EXAMPLE OF INDUSTRY INITIATED PRACTICE

- ***COMPOSITE BEAMS***
- **FIRST STRUCTURES ~1935**
- **RESEARCH AT ILLINOIS AND LEHIGH 1950s**
- **AASHO ROAD TEST BRIDGES 1959-61**
- **BOOK BY VIEST, FOUNTAIN, SINGLETON, 1958**
- **First in AASHO Standard 1957**
- **First in AISC Specification 1963**
- **Continuous research up to this date and beyond**

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EXAMPLE OF RESEARCH INITIATED PRACTICE

- ***PLASTIC DESIGN AND INELASTIC INSTABILITY***
- ***Realization around 100 years ago: there is life beyond the elastic limit.***
- ***Column experiments by Engesser (~1890s)***
- ***First tests of plastic mechanism (1914, Budapest)***
- ***Tests, theory and practice (John Baker, 1930s and 1940s)***

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FROM: **L. H. Gillette, (1980), "The First 60 Years, American Institute of Steel Construction, 1921-1980", AISC**

During the Year [1949], the AISC supported work at Lehigh University dealing with the ultimate strength of welded rigid frames figured prominently in technical discussions at a symposium on plasticity sponsored by the Navy. Professor J. F. Baker, whose work at Cambridge University in England supplemented Lehigh's, visited the United States. He provided members of the Welding Research Council (WRC) and staff members of Lehigh University the opportunity to exchange notes. His visit led to a correlation of the programs at Cambridge and Lehigh".

Major sponsors of research on plastic design: AISC, AISI, USN, WRC, NSF

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PLASTIC DESIGN AT LEHIGH 1950s-1970s

- ***Plastic design leads to a better understanding of behavior under load, and it gives economy***
- ***Inelastic stability is much more difficult than elastic stability: research had to proceed on both fronts.***
- ***Theory alone was not enough: testing had to be integral part of the development***
- ***Research was not enough: results must be directed to usefulness in practice.***

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PLASTIC DESIGN RESEARCH RESULTS

- *Continuous beam and frame design*
- *Column formulas*
- *Interaction equations for beam-columns*
- *Connection design rules (welded and bolted joints)*
- *Multi-story design methods*
- *Post-buckling strength of plate girders is recognized*
- *Many applications in seismic design*
- *Applications in bridge design*
- *SEISMIC DESIGN*
- *Etc.*

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FRITZ ENGINEERING LABORATORY RESEARCH ON MULTI-STORY FRAMES

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STABILITY LIMITS IN AISC

- *ELEMENT STABILITY:*
- *LOCAL BUCKLING*
- *Width- thickness limits*
- *Compact*
- *Non-compact*
- *Slender*

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STABILITY LIMITS IN AISC

- *MEMBER STABILITY*
- *Flexural buckling*
- *Lateral-Torsional Buckling*

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STABILITY CONCERNS IN AISC

- ***FRAME STABILITY***
- ***Effective length***

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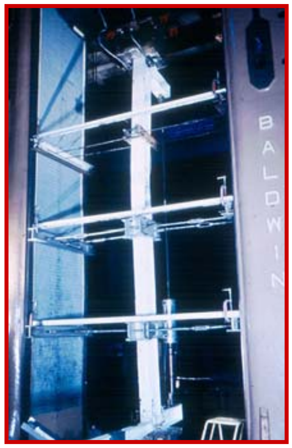
STABILITY CONCERNS IN AISC

- ***Interaction equations***
- ***Beam-Column Design***



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EVOLUTION OF SAFETY CONCEPTS IN AISC SPECIFICATIONS

- ***1923-1963: ALLOWABLE STRESS DESIGN***, $F_{allowable} >= f_{required}$, $F_b=0.6F_y$
- ***1963-1989: LIMIT DESIGN* DISGUISED IN ASD FORMAT**, $F_b=0.66F_y$
- ***1986-FORSEEABLE FUTURE: LOAD AND RESISTANCE FACTOR DESIGN, MULTIPLE LOAD FACTORS AND RESISTANCE FACTORS***

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THANK YOU!

CHAIN BRIDGE, BUDAPEST, 1840's

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CEU/PDH Certificates

Within 2 business days…

- You will receive an email on how to report attendance from: registration@aisc.org.
- Be on the lookout: Check your spam filter! Check your junk folder!
- Completely fill out online form. Don't forget to check the boxes next to each attendee's name!

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CEU/PDH Certificates

Within 2 business days…

- You will receive a link to the reporting site (URL will be provided in the forthcoming email).
- Username: Same as AISC website username.
- Password: Same as AISC website password.

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There's always a solution in steel.

Thank You

Please give us your feedback!
Survey at conclusion of webinar.

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