Structural Steel Design
LRFD Method

Third Edition

CHAPTER

1

INTRODUCTION TO STRUCTURAL STEEL DESIGN

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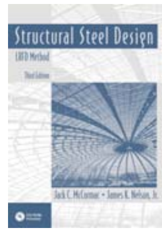
Part II – Structural Steel Design and Analysis

FALL 2002



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ENCE 355 - Introduction to Structural Design

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Advantages of Steel as a Structural Material

- It is interesting to know that steel was not economically made in the United States until late in the nineteenth century.
- However, since then steel has become the predominate material for the construction of bridges, buildings, towers, and other structures.

Advantages of Steel as a Structural Material

- Steel exhibits desirable physical properties that makes it one of the most versatile structural material in use.
- Its great strength, uniformity, light weight, ease of use, and many other desirable properties makes it the material of choice for numerous structures such as steel bridges, high rise buildings, towers, and other structures.

Advantages of Steel as a Structural Material

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Construction of Golden Gate Bridge (San Francisco, CA)

Advantages of Steel as a Structural Material

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Advantages of Steel as a Structural Material

- The many advantages of steel can be summarized as follows:
  - High Strength
    - This means that the weight of structure that made of steel will be small.
  - Uniformity
    - Properties of steel do not change as oppose to concrete.
  - Elasticity
    - Steel follows Hooke's Law very accurately.

Advantages of Steel as a Structural Material

- Ductility
  - A very desirable of property of steel in which steel can withstand extensive deformation without failure under high tensile stresses, i.e., it gives warning before failure takes place.
- Toughness
  - Steel has both strength and ductility.
- Additions to Existing Structures
  - Example: new bays or even entire new wings can be added to existing frame buildings, and steel bridges may easily be windened.

Disadvantages of Steel as a Structural Material

- Although steel has all this advantages as structural material, it also has many disadvantages that make reinforced concrete as a replacement for construction purposes.
- For example, steel columns sometimes can not provide the necessary strength because of buckling, whereas R/C columns are generally sturdy and massive, i.e., no buckling problems occurs.

Disadvantages of Steel as a Structural Material

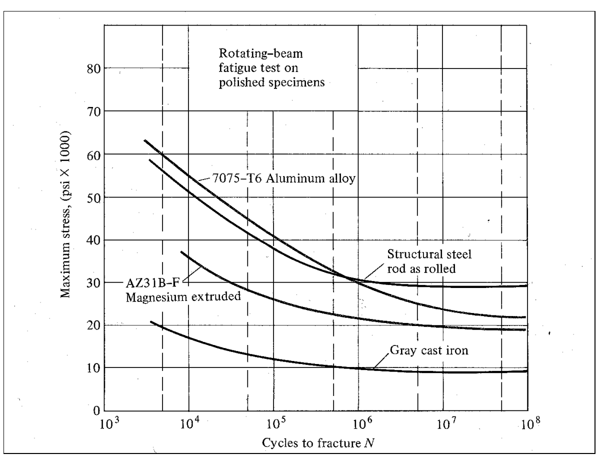
- The many disadvantages of steel can be summarized as follows:
  - Maintenance Cost
    - Steel structures are susceptible to corrosion when exposed to air, water, and humidity. They must be painted periodically.
  - Fireproofing Cost
    - Steel is incombustible material, however, its strength is reduced tremendously at high temperatures due to common fires

Disadvantages of Steel as a Structural Material

– Susceptibility to Buckling
  - For most structures, the use of steel columns is very economical because of their high strength-to-weight ratios. However, as the length and slenderness of a compressive column is increased, its danger of buckling increases.

– Fatigue
  - The strength of structural steel member can be reduced if this member is subjected to cyclic loading.

Disadvantages of Steel as a Structural Material



S = stress range
N = number of cycles

Figure 1. *S-N* Curves for Various Materials (Byars and Snyder, 1975)

Disadvantages of Steel as a Structural Material

- Brittle Fracture
  - Under certain conditions steel may lose its ductility, and brittle fracture may occur at places of stress concentration. Fatigue type loadings and very low temperatures trigger the situation.

Early Uses of Iron and Steel

- 1777-1779: Metal as structural material began with cast iron, used on a 100-ft (30-m) arch span, which was built in England.
- 1780 –1820: A number of cast-iron bridges were built during this period.
- 1846 -1850: The Brittania Bridge over Menai Strait in Wales was built.

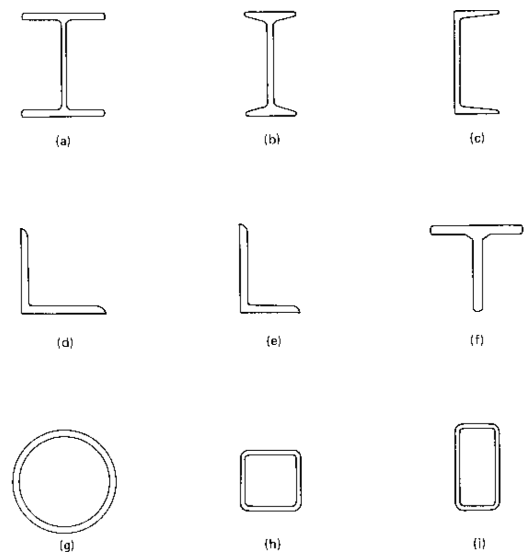
Early Uses of Iron and Steel

- 1840: Wrought iron began replacing cast iron soon.
- 1855: Development of the Bessemer process, which help producing steel in large quantities and at cheaper prices.
- 1989: Steel shapes having yield strength of 24,000 to 100,000 psi were produced.

Steel Sections

- Rolled Sections
  - Structural steel can be economically rolled into a wide variety of shapes and sizes without appreciably changing its physical properties.
  - Usually the most desirable members are those with large moments of inertia in proportion to their areas.
  - The **I**, **T**, and **C** shapes, so commonly used, fall into this class.

Steel Sections



Steel Sections

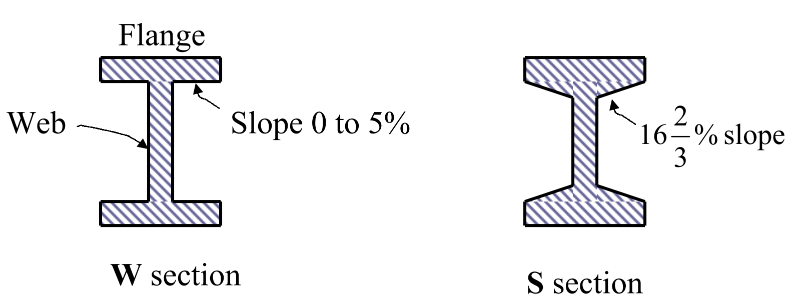
Steel Sections

- Rolled Sections
  - Steel section are usually designated by the shapes of their cross sections.
  - As examples, there are angles, tees, zees, and plates.
  - It is necessary, however, to make a definite distinction between American standard beams (called **S** beams) and wide-flange beams (called **W** beams) as they are both **I** shaped.

Steel Sections

- Rolled Sections

I-Shaped Sections



Steel Sections

- Designation System
  - Structural shapes are abbreviated by a certain system usually described in LRFD manual for use in drawings, specifications, and designs.
  - This system has been standardized so that all steel mills can use the same identification for purposes of ordering, billing, etc.

Steel Sections

- Designation System

  Some examples of this abbreviation system are as follows:

  1. A W17 × 117 is a **W** section approximately 27 in. deep weighing 114 b/ft.
  2. An S12 × 35 is an **S** section 12 in. deep weighing 35 lb/ft.
  3. An HP12 × 74 is bearing pile section which is approximately 12 in. deep weighing 74 lb/ft.

Steel Sections

- Designation System
  4. A C10 × 30 is a channel section 10 in. deep weighing 30 lb/ft.
  5. An MC18 × 58 is a miscellaneous channel 18 in. deep weighing 58 lb/ft, which cannot be classified as a **C** shape because of its dimensions.
  6. An L6 × 6 × ½ is an equal leg angle, each leg being 6 in long and ½ in. thick.

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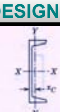


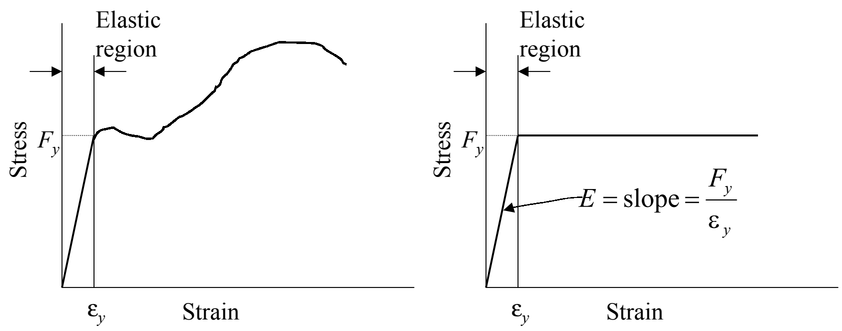
TABLE B-6 Standard Channels (SI Units)

Designation*	Area (mm²)	Depth (mm)	FLANGE Width (mm)	FLANGE Thickness (mm)	Web Thickness (mm)	AXIS X–X I (10^6 mm⁴)	AXIS X–X S (10^3 mm³)	AXIS X–X r (mm)	AXIS Y–Y I (10^6 mm⁴)	AXIS Y–Y S (10^3 mm³)	AXIS Y–Y r (mm)	x_c (mm)
C457 × 86	11030	457.2	106.7	15.9	17.8	281	1230	160	7.41	87.2	25.9	21.9
× 77	9870	457.2	104.1	15.9	15.2	261	1140	163	6.83	83.1	26.4	21.8
× 68	8710	457.2	101.6	15.9	12.7	241	1055	167	6.29	79.0	26.9	22.0
× 64	8130	457.2	100.3	15.9	11.4	231	1010	169	5.99	76.9	27.2	22.3
C381 × 74	9485	381.0	94.4	16.5	18.2	168	882	133	4.58	61.9	22.0	20.3
× 60	7615	381.0	89.4	16.5	13.2	145	762	138	3.84	55.2	22.5	19.7
× 50	6425	381.0	86.4	16.5	10.2	131	688	143	3.38	51.0	23.0	20.0
C305 × 45	5690	304.8	80.5	12.7	13.0	67.4	442	109	2.14	33.8	19.4	17.1
× 37	4740	304.8	77.4	12.7	9.8	59.9	395	113	1.86	30.8	19.8	17.1
× 31	3930	304.8	74.7	12.7	7.2	53.7	352	117	1.61	28.3	20.3	17.7
C254 × 45	5690	254.0	77.0	11.1	17.1	42.9	339	86.9	1.64	27.0	17.0	16.5
× 37	4740	254.0	73.3	11.1	13.4	38.0	298	89.4	1.40	24.3	17.2	15.7
× 30	3795	254.0	69.6	11.1	9.6	32.8	259	93.0	1.17	21.6	17.6	15.4
× 23	2895	254.0	66.0	11.1	6.1	28.1	221	98.3	0.949	19.0	18.1	16.1
C229 × 30	3795	228.6	67.3	10.5	11.4	25.3	221	81.8	1.01	19.2	16.3	14.8
× 22	2845	228.6	63.1	10.5	7.2	21.2	185	86.4	0.803	16.6	16.8	14.9
× 20	2540	228.6	61.8	10.5	5.9	19.9	174	88.4	0.733	15.7	17.0	15.3
C203 × 28	3555	203.2	64.2	9.9	12.4	18.3	180	71.6	0.824	16.6	15.2	14.4
× 20	2605	203.2	59.5	9.9	7.7	15.0	148	75.9	0.637	14.0	15.6	14.0
× 17	2180	203.2	57.4	9.9	5.6	13.6	133	79.0	0.549	12.8	15.9	14.5
C178 × 22	2795	177.8	58.4	9.3	10.6	11.3	127	63.8	0.574	12.8	14.3	13.5
× 18	2320	177.8	55.7	9.3	8.0	10.1	114	66.0	0.487	11.5	14.5	13.3
× 15	1850	177.8	53.1	9.3	5.3	8.87	99.6	69.1	0.403	10.2	14.8	13.7
C152 × 19	2470	152.4	54.8	8.7	11.1	7.24	95.0	54.1	0.437	10.5	13.3	13.1
× 16	1995	152.4	51.7	8.7	8.0	6.33	82.9	56.4	0.360	9.24	13.4	12.7
× 12	1550	152.4	48.8	8.7	5.1	5.45	71.8	59.4	0.288	8.06	13.6	13.0
C127 × 13	1705	127.0	47.9	8.1	8.3	3.70	58.3	46.5	0.263	7.37	12.4	12.1
× 10	1270	127.0	44.5	8.1	4.8	3.12	49.2	49.5	0.199	6.19	12.5	12.3
C102 × 11	1375	101.6	43.7	7.5	8.2	1.91	37.5	37.3	0.180	5.62	11.4	11.7
× 8	1025	101.6	40.2	7.5	4.7	1.60	31.6	39.6	0.133	4.64	11.4	11.6
C76 × 9	1135	76.2	40.5	6.9	9.0	0.862	22.6	27.4	0.127	4.39	10.6	11.6
× 7	948	76.2	38.0	6.9	6.6	0.770	20.3	28.4	0.103	3.82	10.4	11.1
× 6	781	76.2	35.8	6.9	4.6	0.691	18.0	29.7	0.082	3.31	10.3	11.1

*C means channel, followed by the nominal depth in mm, then the mass in kg per meter of length.

Stress-Strain Relationships in Structural Steel

■ Idealized Relationships



(a) As Determined by Tensile Test **(b) Idealized**

Modern Structural Steels

■ Properties of Modern Steels

– The properties of steel used can be greatly changed by varying the quantities of carbon present and adding other elements such as

- Silicon
- Nickel
- Manganese, and
- Copper

– A steel having a significant amount of these elements is referred to as an *alloy steel*.

Modern Structural Steels

- Yield Point of Modern Steels
  - In the past, a structural carbon steel designated as A36 and having yield stress of F_y = 36 ksi was the commonly used structural steel.
  - Today, a steel having F_y = 50 ksi can be produced and sold at almost the same price as 36 ksi steel.
  - Structural steels are generally grouped into several major ASTM classifications:

ASTM = American Society for Testing and Materials

Modern Structural Steels

- Yield Point of Modern Steels
  - The carbon steels A36, A53, A500, A501, and A529.
  - The high-strength low alloy steels A572, A618, A913, and A992.
  - The corrosion resistant high-strength low-alloy steels A242, A588, and A847

Considerable information is presented for each of these steels in Part 2 of The LRFD Manual.

Uses of High-Strength Steels

- There are indeed ultra-high-strength steels that have yield strengths from 160 to 300 ksi. These steels have not been included in the LRFD Manual because they have not been assigned ASTM numbers.
- The steel industry is now experimenting with steels with yield stresses from 200 to 300 ksi.

Uses of High-Strength Steels

- It is believed hat steels with 500 ksi yield strength will be made available within few years.
- The theoretical biding force between iron atoms has been estimated to be in excess of 4000 ksi.

Uses of High-Strength Steels

- Factors that Lead to the Use of High-strength Steels:
  1. Superior corrosion resistance.
  2. Possible savings in shipping, erection, and foundation costs caused by weight savings.
  3. Use of shallow beams permitting smaller floor depths.
  4. Possible savings in fireproofing because smaller members can be used.

Responsibilities of the Structural Designer and Engineer

- The structural designer or engineer must learn to arrange and proportion the parts of structures so that they can be practically erected and will have sufficient strength and reasonable economy. Some of the items that must be considered include
  - Safety
  - Cost
  - Practicality

Responsibilities of the Structural Designer and Engineer

- Safety
  - Not only must the frame of a structure safely support the loads to which it is subjected, but also it must support them in such a manner that deflections and vibrations are not so great as to frighten the occupants or to cause unsightly cracks.
- Cost
  - The engineer or designer needs to keep in mind the factors that can lower cost without sacrificing the strength, e.g., the use of standard-size members, simple connections, etc.

Responsibilities of the Structural Designer and Engineer

- Practicality
  - Designers and engineers need to understand fabrication methods, and should try to fit their work to the fabrication facilities available.
  - The more the designer knows about the problems, tolerances, and clearances in shop and field the more probable it is that reasonable, practical, and economical designs will be produced.

Could I get this thing together if I were sent out to do it??

Computers and Structural Steel Design

- Personal computers have drastically changed the way steel structures are analyzed and designed.
- Many of the commercial structural software packages can perform
  - Structural Analysis, and
  - Structural Design

Computers and Structural Steel Design

- The need for these programs stems from the fact that the calculations involved in both the design and analysis of an engineering system are quite time-consuming.
- With the use of a computer, the design engineer greatly can reduce the time required to perform these calculations.

Computers and Structural Steel Design

- Although computers do increase design productivity, they also tend to reduce the engineer's "feel" for the structure.
- This can be a particular problem for young engineers with very little design experience.
- Computers should not be looked at as black boxes that can do powerful things for us.

Computers and Structural Steel Design

- Knowledge and understanding of the basic engineering principals are prerequisites for the effective implementation of any design.
- No matter how impressive your tool chest, you will be hard-pressed to repair a car if you do not understand how it works.

Computers and Structural Steel Design

- This specially true when using computers to perform structural designs and analyses.
- Although they have powerful potential utility, computers are particularly useless without a fundamental understanding of how engineering systems work.