## CHAPTER 2: STRUCT. STEEL DESIGN

### DESIGN PHILOSOPHIES (See pg 2-10 to 2-73 AISC)

REQ'D STRENGTH ≤ AVAIL. STRENGTH

### ALLOWABLE STRENGTH DESIGN (ASD)

REQ'D STRENGTH ≤ Allowable Strength

where Allow Strength = Avail Strength / F.S. = Nominal Strength / FS

$$\text{Allow Strength} = \frac{\text{Avail Strength}}{F.S.} = \frac{\text{Nominal Strength}}{FS}$$

FS = typical FS = 1.5, 1.67, 2.0 ← Rupture States

1.67 ← Yielding State

denoted $\Omega$

REQ'D Strength = Axial load, bending moment, shear, etc.

(see p2-12 AISC)

## ALLOW. STRESS DESIGN

$$\text{Max Applied Stress} \le \frac{\text{Nominal Stress}}{FS}$$

Allow Stress

## LOAD RESISTANCE FACTORED DESIGN (LRFD)

$$\underbrace{\sum_{i=1}^{n} (\text{load}_i \times \text{load factor}_i)}_{\text{Factored Load Effects}} \le \underbrace{\text{Nominal Resistance} \times \text{Resistance Factor}}_{\text{factored strength effects}}$$

Factored Load Effects ≤ factored strength effects

* Structures are subjected to multiple loads (wind, snow, dead, live, thermal, etc.)

p 2-11 Resistance Factors

ASD FUNDAMENTAL EQN:

$$P_{service} \le \frac{P_{nominal}}{\Omega} \quad \Big\}\ \text{Allow. Stress or Strength}$$

Not Factored

LRFD FUND. EQN.:

$$P_u \le \phi P_n$$

Factored

$P_n$ = nom. strength

$\phi$ = res. factor

0.9 for yielding

0.75 for rupture

$P_u$ = compute exactly same way for ASD

NOTE: $\phi = \frac{1.5}{\Omega}$ - or - $\Omega = \frac{1.5}{\phi}$

AISC SPECIFICATION

| | | |
|---|---|---|
| $1^{st}$ Ed. | 1923 | } allow stress design |
| $9^{th}$ Ed. | 1989 | |
| $1^{st}$ Ed. | 1986, | LRFD ONLY |
| $3^{rd}$ Ed. | 2001 | " |
| $13^{th}$ Ed. | 2005 | LRFD + ASD (Strength) |
| $15^{th}$ Ed. | current | |

(p2-28)

SUMMARY

based on probability

| | LOAD | STRENGTH |
|---|---|---|
| LRFD | FACTORED | FACTORED |
| ASD | ACTUAL | REDUCE |

## LOAD COMBINATIONS

- Based on ASCE 7, pg 25 Segui
- Pressure & self-restraining forces are not applicable to frames in steel bldg.

three parts: the main body, the appendixes,
alphabetically organized into Chapters A
headings are labeled with the chapter des-
Furthermore, subdivisions are numerically labeled.
steel authorized are listed in Chapter A,
A3, "Material," and, under it, Section 1,
body of the Specification is followed by
followed by the Commentary, which gives
provisions of the Specification. Its orga-
the Specification, so material applicable to a

both U.S. customary and metric (SI) units.
are expressed in non-dimensional form
modulus of elasticity in symbolic form,
is not possible, U.S. customary units are
Although there is a strong move to met-
design in the United States is still done
uses only U.S. customary units.

## RESISTANCE FACTORS, COMBINATIONS FOR LRFD

(2.5)

component under consideration

The summation on
of load effects (including,
load effect can be associ-
effect have a different
particular load effect will
Equation 2.5 can also

(2.6)

moments)

load com-



give them, then ASCE 7 (ASCE, 2016) should be used. The load factors and load combinations in this standard are based on extensive statistical studies and are prescribed by most building codes.

The following load combinations are based on the combinations given in ASCE 7-16:

LRFD

Combination 1: $1.4D$
Combination 2: $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$
Combination 3: $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (0.5L \text{ or } 0.5W)$
Combination 4: $1.2D + 1.0W + 0.5(L_r \text{ or } S \text{ or } R)$ +0.5L
Combination 5: $0.9D + 1.0W$

where

$D$ = dead load
$L$ = live load due to occupancy
$L_r$ = roof live load
$S$ = snow load
$R$ = rain or ice load*
$W$ = wind load

Note that earthquake (seismic) loading is absent from this list. If earthquake loads must be considered, consult the governing building code or ASCE 7.

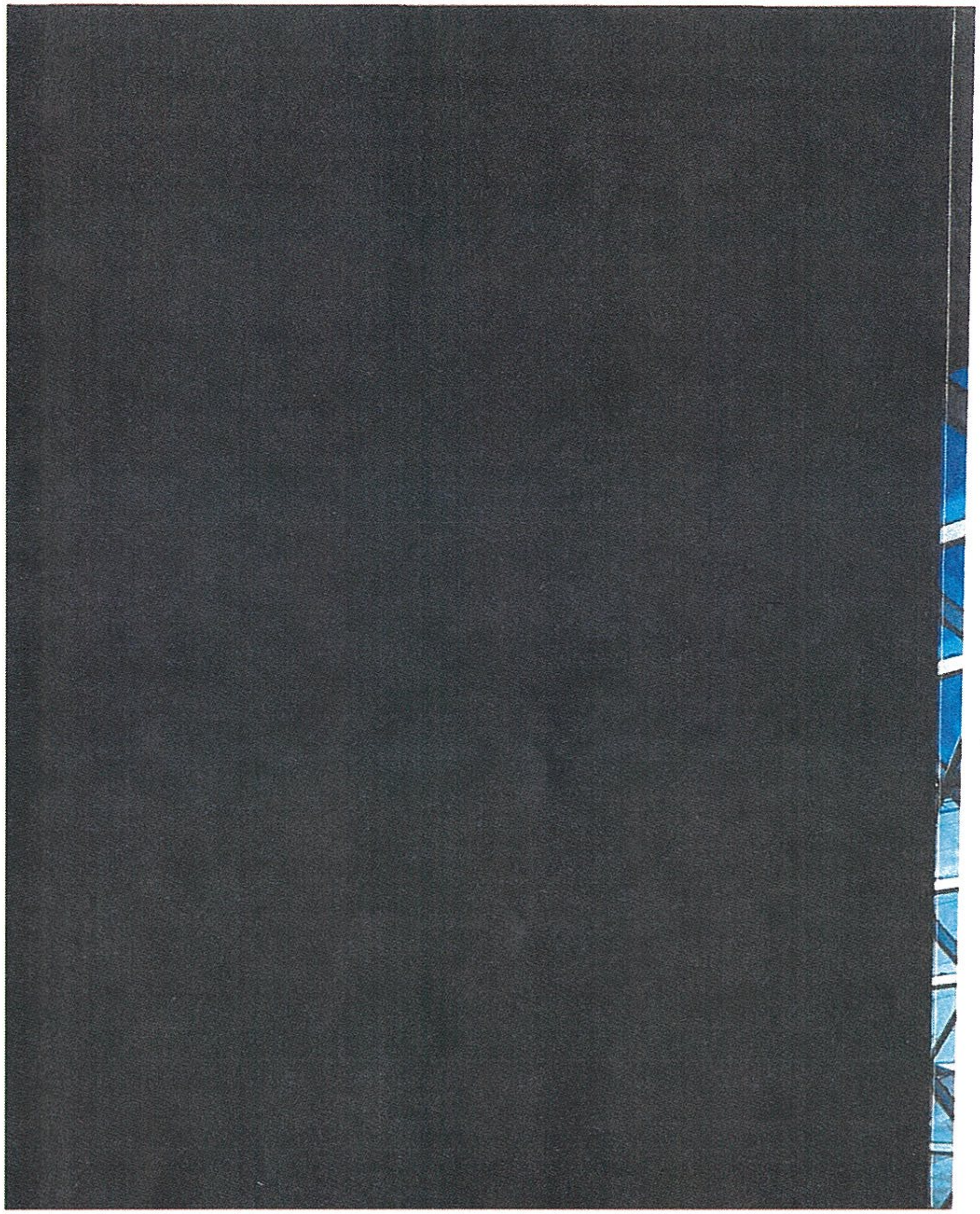
In combinations 3 and 4, the load factor on $L$ should be increased from 0.5 to 1.0 if $L$ is greater than 100 pounds per square foot and for garages or places of public assembly.

In combinations with wind load, you should use a direction that produces the worst effect.

Combination 5 accounts for the possibility of dead load and wind load counteracting each other; for example, the net load effect could be the difference between $0.9D$ and $1.0W$. (Wind loads may tend to overturn a structure, but the dead load will have a stabilizing effect.)

As previously mentioned, the load factor for a particular load effect is not the same in all load combinations. For example, in combination 2 the load factor for the live load $L$ is 1.6, whereas in combination 3, it is 0.5. The reason is that the live load is being taken as the dominant effect in combination 2, and one of the three effects, $L_r$, $S$, or $R$, will be dominant in combination 3. In each combination, one of the effects is considered to be at its "lifetime maximum" value and the others at their "arbitrary point in time" values.

The resistance factor $\phi$ for each type of resistance is given by AISC in the Specification chapter dealing with that resistance, but in most cases, one of two values will be used: 0.90 for limit states involving yielding or compression buckling and 0.75 for limit states involving rupture (fracture).





## 2.4 SAFETY FACTORS AND LOAD COMBINATIONS FOR ASD

For allowable strength design, the relationship between loads and strength (Equation 2.1) can be expressed as

$$R_a \leq \frac{R_n}{\Omega} \tag{2.7}$$

where

$R_a$ = required strength
$R_n$ = nominal strength (same as for LRFD)
$\Omega$ = safety factor
$R_n/\Omega$ = allowable strength

The required strength $R_a$ is the sum of the service loads or load effects. As with LRFD, specific combinations of loads must be considered. Load combinations for ASD are also given in ASCE 7. The following combinations are based on ASCE 7-16:

ASD

Combination 1: $D$
Combination 2: $D + L$
Combination 3: $D + (L_r \text{ or } S \text{ or } R)$
Combination 4: $D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
Combination 5: $D + 0.6W$
Combination 6: $D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R)$
Combination 7: $0.6D + 0.6W$

The factors shown in these combinations are not load factors. The 0.75 factor in some of the combinations accounts for the unlikelihood that all loads in the combination will be at their lifetime maximum values simultaneously.

Corresponding to the two most common values of resistance factors in LRFD are the following values of the safety factor $\Omega$ in ASD: For limit states involving yielding or compression buckling, $\Omega = 1.67$. For limit states involving rupture, $\Omega = 2.00$. The relationship between resistance factors and safety factors is given by

$$\Omega = \frac{1.5}{\phi} \tag{2.8}$$

For reasons that will be discussed later, this relationship will produce similar designs for LRFD and ASD, under certain loading conditions.

If both sides of Equation 2.7 are divided by area (in the case of axial load) or section modulus (in the case of bending moment), then the relationship becomes

$$f \leq F$$

EXAMPLE

GIVEN: A Column shown below is subjected to the service loads shown


$P_D = 24^k$ $M_D = 10^{k\text{-}ft}$

$P_L = 32^k$ $M_W = 18^{k\text{-}ft}$

REQ'D: Compute the factored load this column must resist.

SOLN: 1) $1.4D \Rightarrow$ $P = 1.4(24^k) = 33.6^k$
$M = 1.4(10^{k\text{-}ft}) = 14^{k\text{-}ft}$

2) $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$ $P = 1.2(24) + 1.6(32) = 80^k$
$M = 1.2(10) = 12^{k\text{-}ft}$

3) $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (0.5L \text{ or } 0.5W)$

$P = 1.2(24) + 0.5(32) = 44.8^k$

$M = 1.2(10) + 0.5(18) = 21^{k\text{-}ft}$

4) $1.2D + 1.0W + 0.5(L_r \text{ or } S \text{ or } R) + 0.5L$

$P = 1.2(24) + 0.5(32) = 44.8^k$

$M = 1.2(10) + 1.0(18) = 30^{k\text{-}ft}$

5) $0.9D + 1.0W$

$P = 0.9(24) + 1.0(0) = 21.6^k$

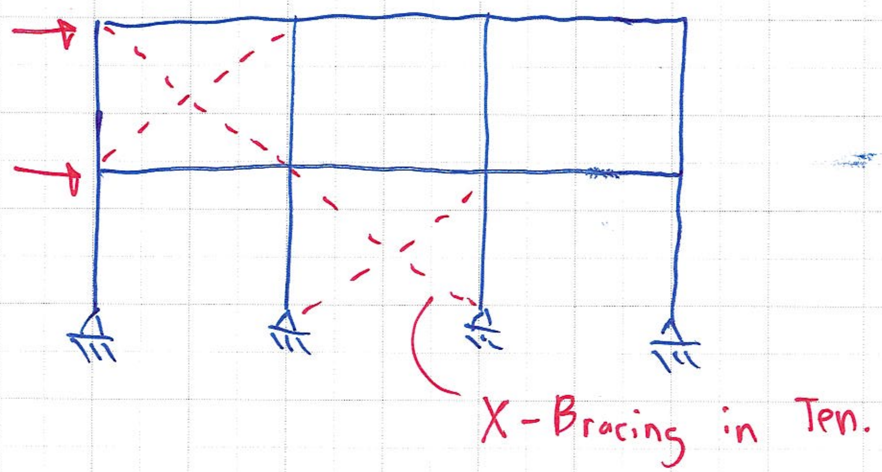
$M = 0.9(10) + 1.0(18) = 27^{k\text{-}ft}$

CONTROLS: #2 @ $P = 80^k$; $M = 12^{k\text{-}ft}$ — 1st Analysis

#4 @ $P = 44.8^k$; $M = 30^{k\text{-}ft}$ — 2nd Analysis

# CHAPTER 3: TENSION MEMBERS

## INTRODUCTION




AISC MANUAL - PART 16 Chapter B, D, J

- "simplest" of all members to design & analyze
- Bracing, Trusses, etc.
- Shapes typ.: angles, double angles ⊥L, channels, WT, W-Shapes, & HSS

  * Rods & Cables are widely used, but not in 446

Stress = $f = \frac{P}{A}$ where $P$ = Axial load
$A$ = CSA (area)
$f$ = axial stress (Avg.)

## APPLICABLE LIMIT STATES

1) GROSS SECT. YIELDING (GSY) — total area
2) NET SECTION RUPTURE / FRACTURE (NSR) → CHAP B
3) BLOCK SHEAR RUPTURE (BSR) → CHAP J

} CHAP D

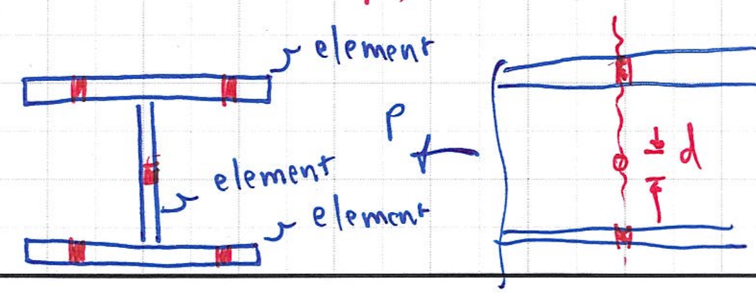
## ANALYSIS & DESIGN OF TENSION MEMBERS

- gross area; Net Area (Chap B, p16.1 - 20)

$A_g$ = gross area = total CSA (Part 1 AISC - Sect. Prop.)

$A_n$ = net area = $A_g - \sum A_{holes}$

where $\sum_{n=1}^{i} d_i t_i = A_{holes}$



$n$ = # of holes

$t_i$ = thick of element

$d_i = d_{hole} + \frac{1}{16}''$ ← for damage

NOTE:

$d_{hole} = d_{bolt} + \frac{1}{16}''$ ← for tolerance/over size (for STD hole)

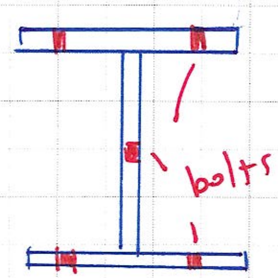
$d_i = d_{bolt} + \frac{1}{16}'' + \frac{1}{16}'' = d_{bolt} + \frac{1}{8}''$

- Net Effective Area (pg 50-57 Segui)

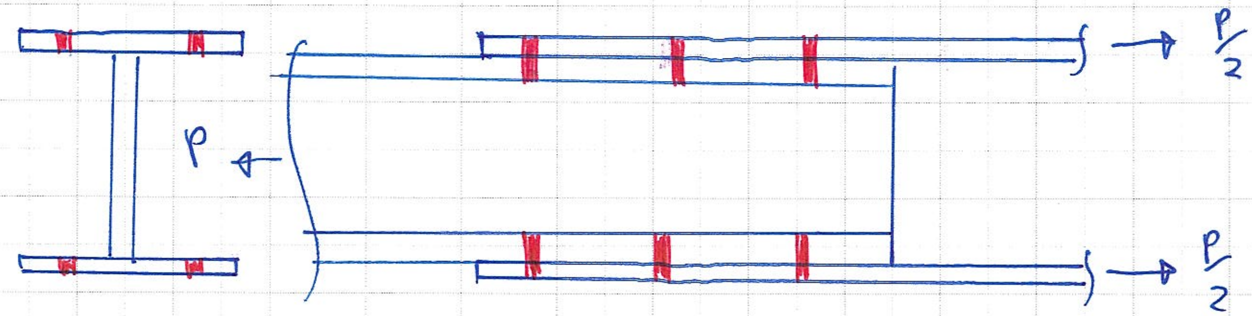
  $A_e$ = eff. net area = $UA_n$

  $U$ = Shear Lag Factor (Table D3.1 p16.1-30)

EXAMPLE




$U = 1.0$




$U < 1.0$