Structural Steel Design
Tension Members

Dr. Seshu Adluri

MEMORIAL UNIVERSITY
Newfoundland & Labrador, Canada
FACULTY OF ENGINEERING & APPLIED SCIENCE

Tension in Nature

- Tension members are the most efficient and economical of all structural elements

Tension Members Used From Primitive Times

- If you want your grand kids to play "Tarzan and the Tension Member," save the forests!

(Wo)Man-made Tension Structures

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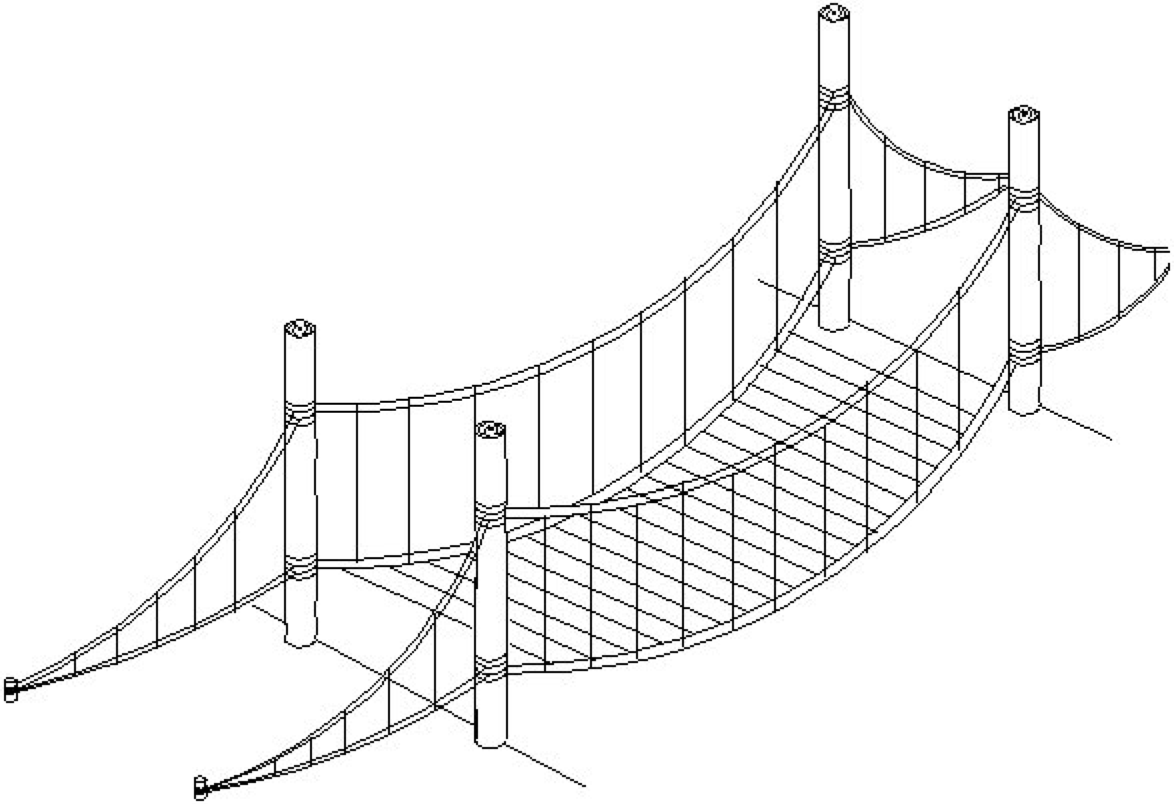
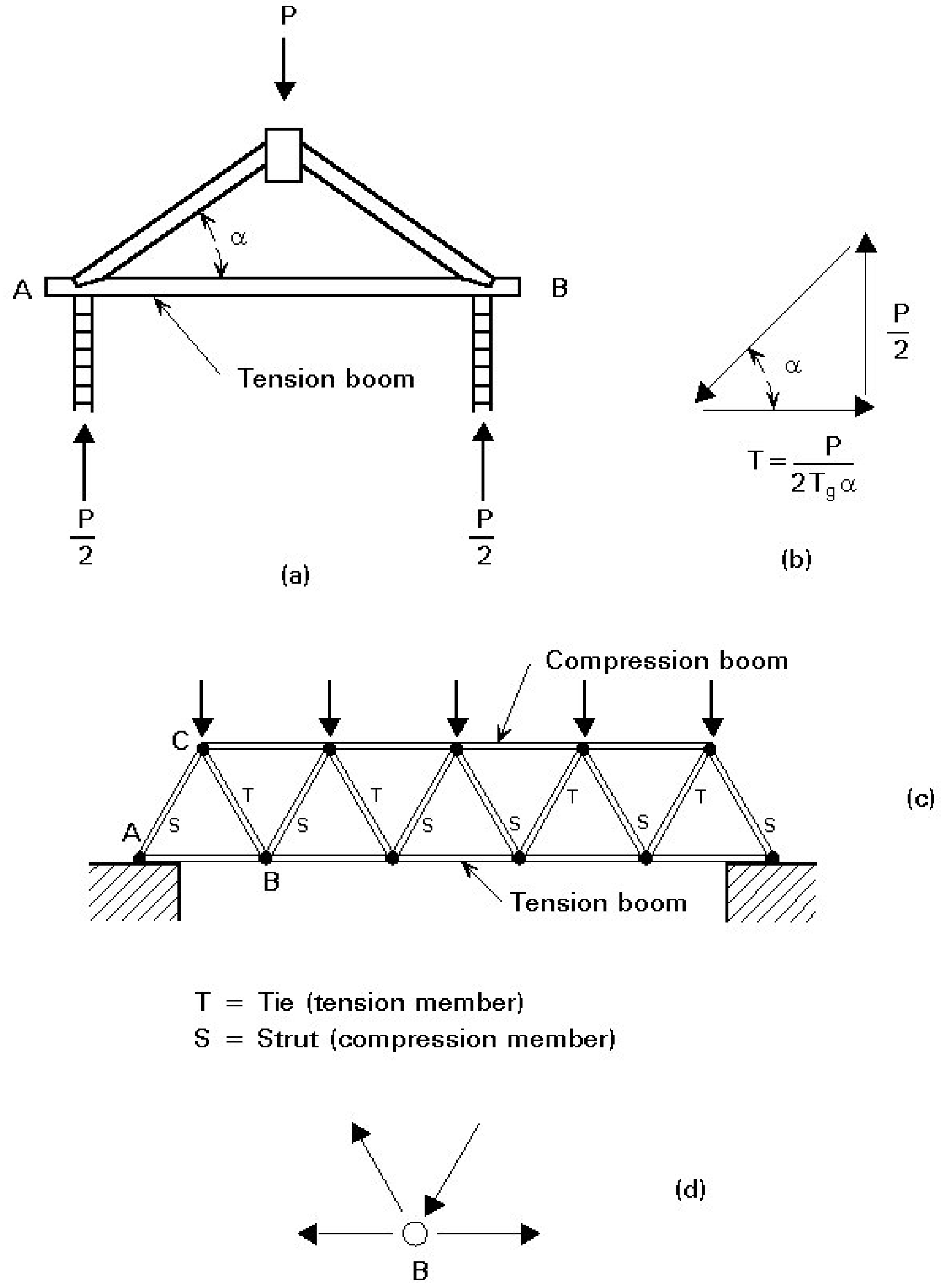


Figure 1 Primitive temporary bridge

Typical tension members



Steel and Tension

- **Steel in Tension**
  - Excellent in Tension (and compression)
  - Very ductile (highly desirable structural property for stress redistribution and safety)
  - Connections induce loss of effective area
    - Bolt holes, etc.
    - Shear lag in outstanding parts (of both bolted and welded connections)

Typical cross-sections

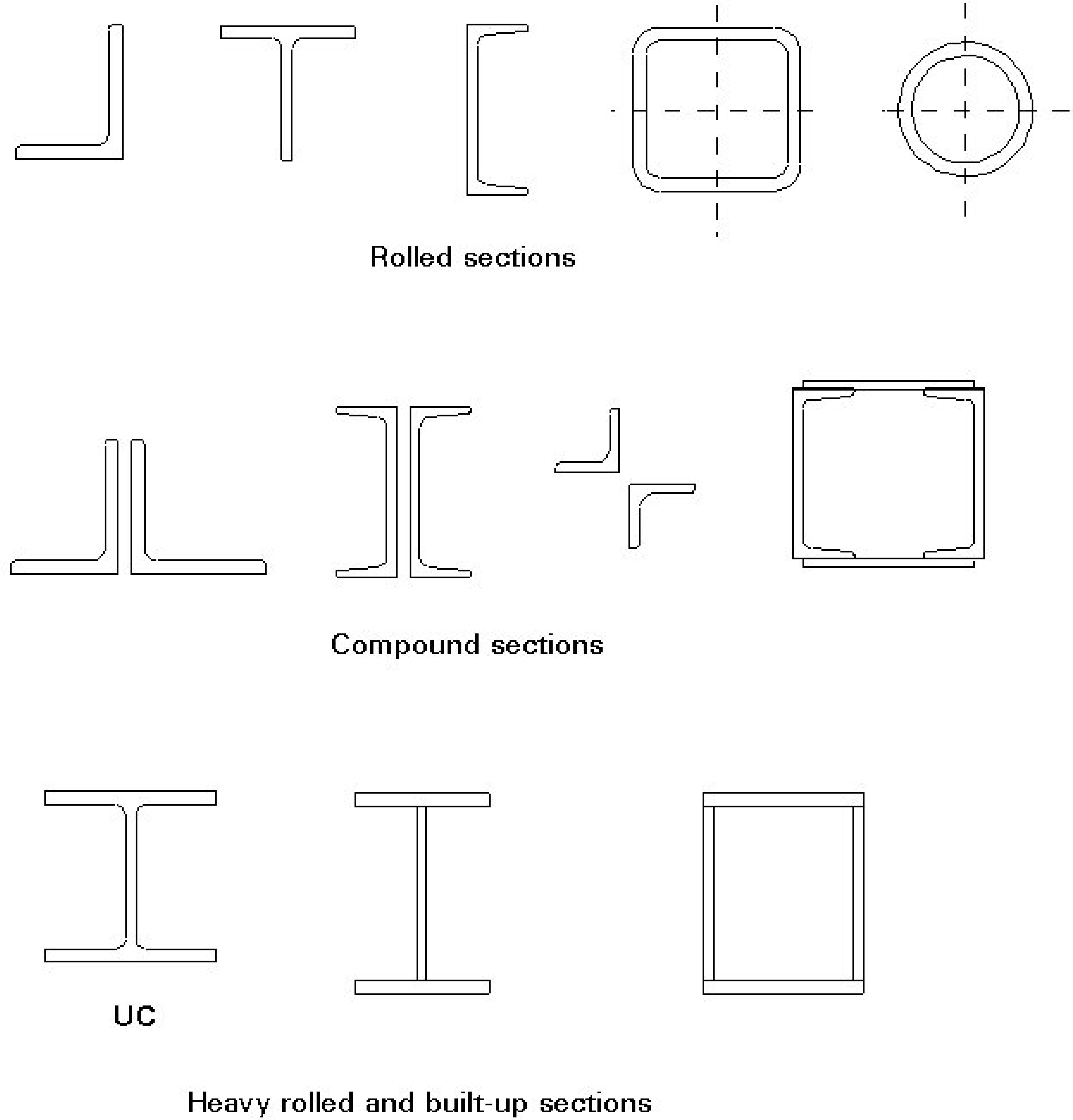


Figure 4 Cross - sections of tension members

Material behaviour

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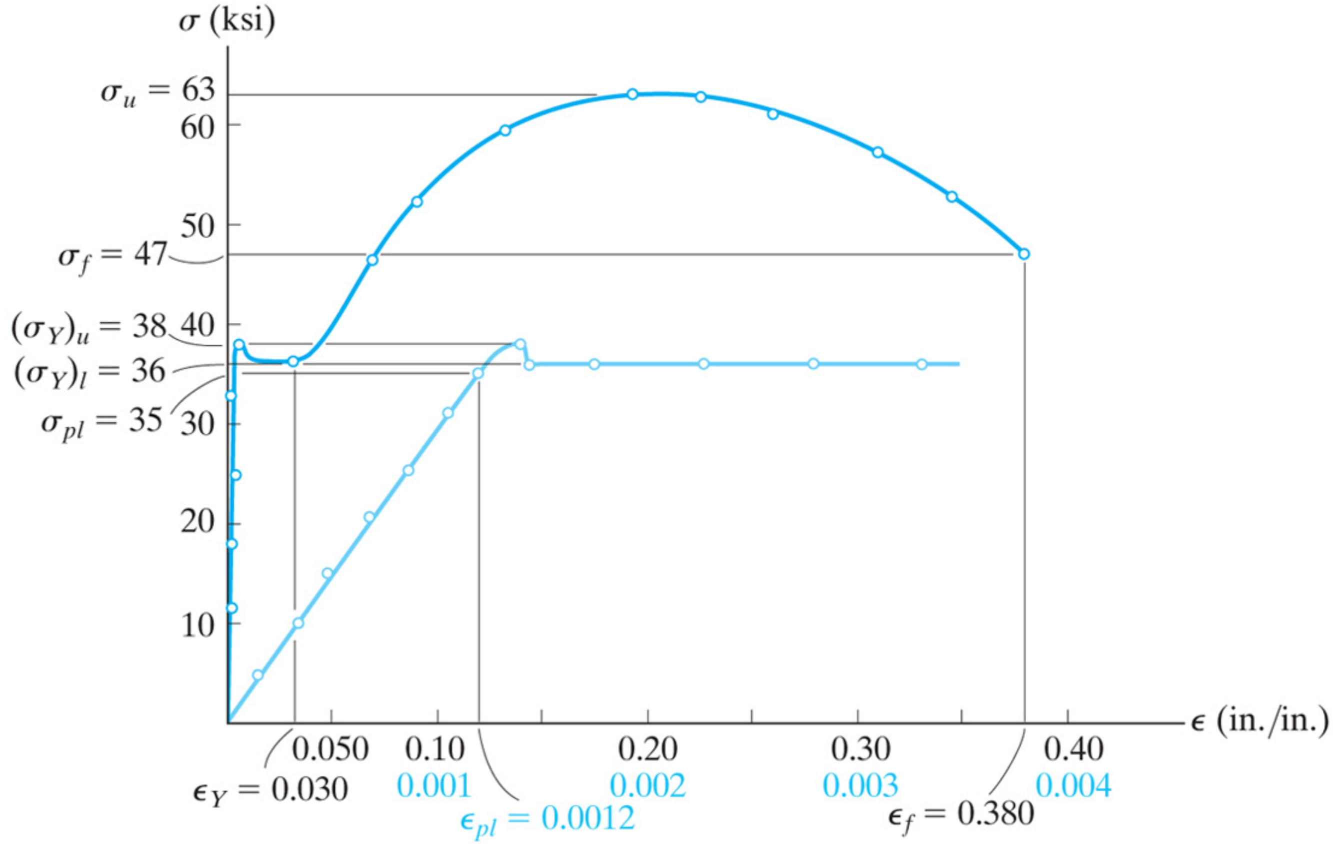

Stress-strain diagram for mild steel

Material behaviour

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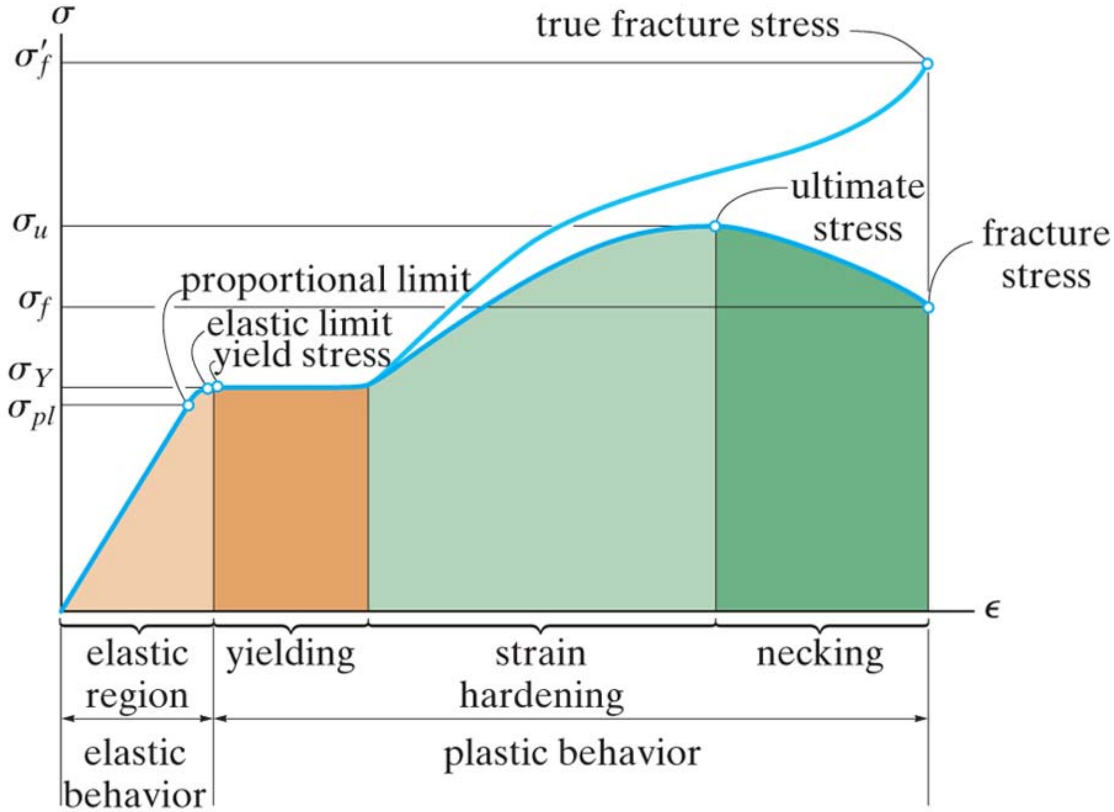
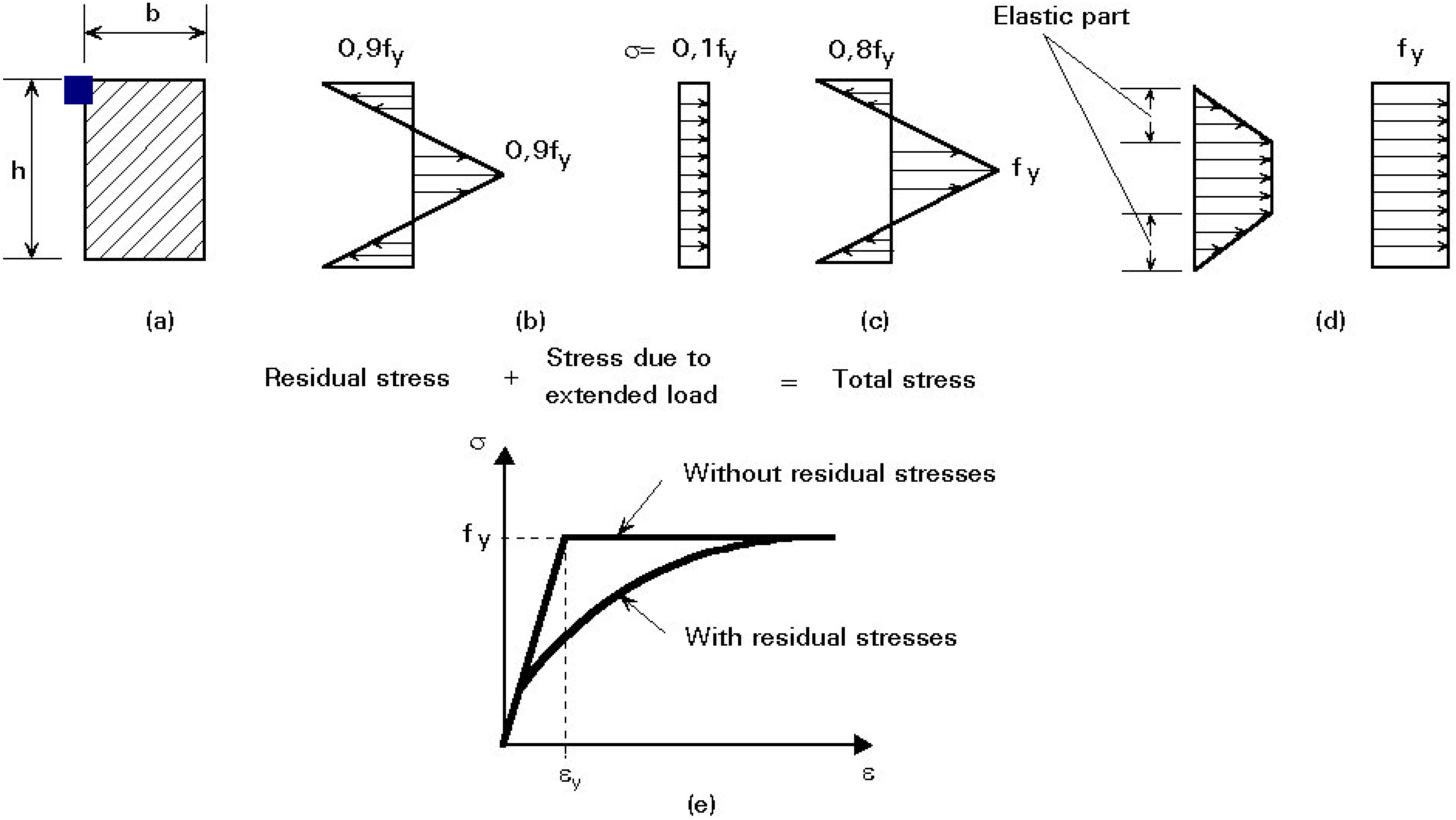


Conventional and true stress-strain diagrams for ductile material (steel) (not to scale)

Stresses in tension members (gross-section)



Stresses in net-section

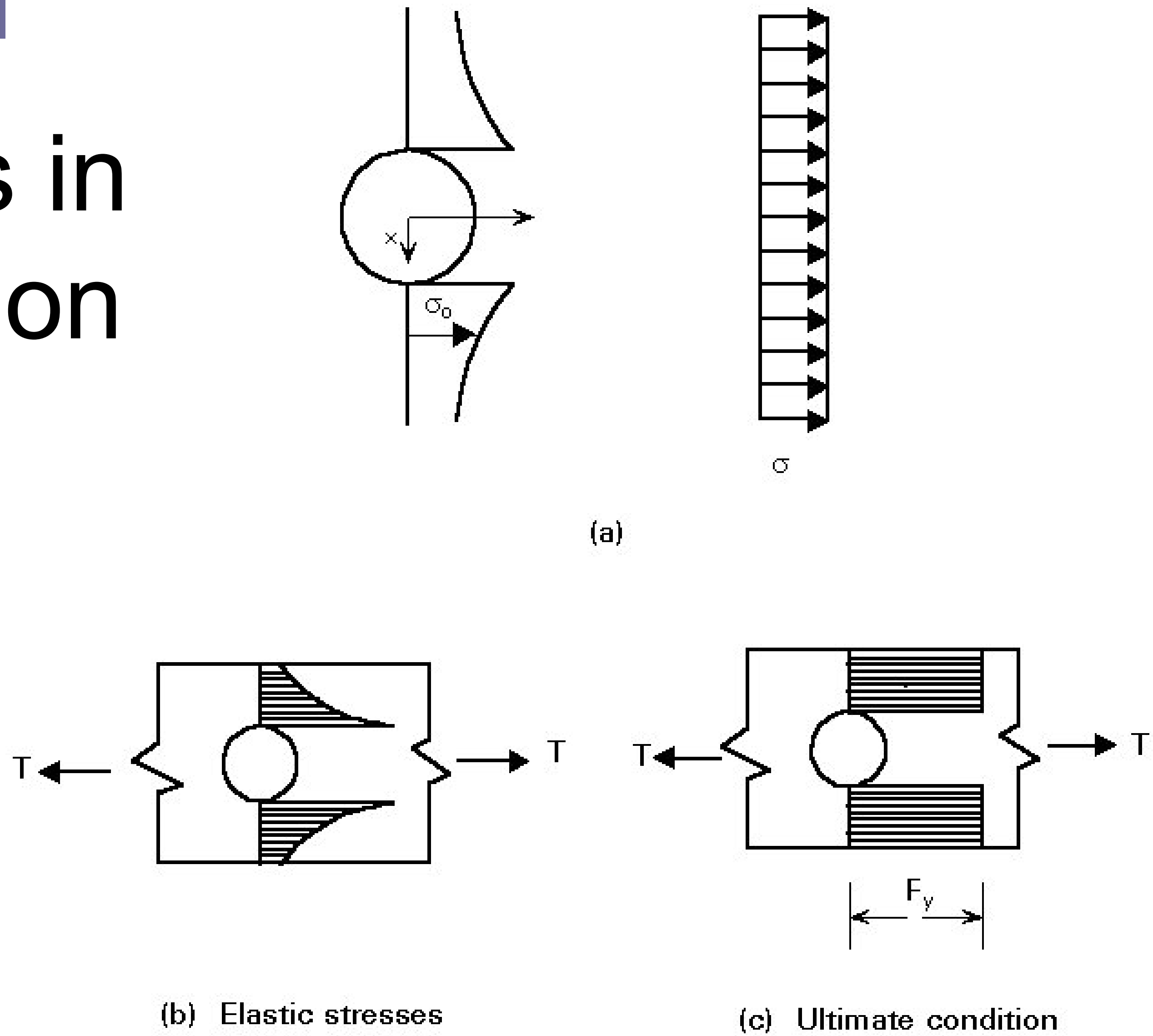


Figure 6 Distribution of stress across a section with holes

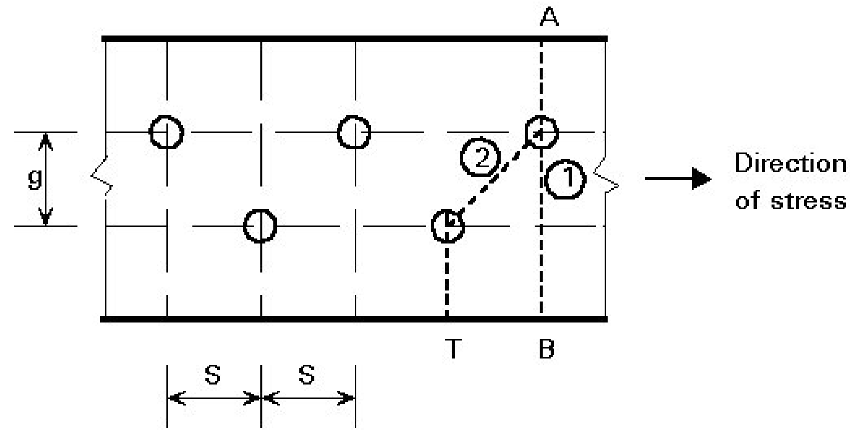
Basic Failure modes

- Yielding of gross c/s
  - Limiting the capacity to yield prevents very large deformations (before strain hardening kicks in)
- Rupture (fracture) of net c/s
  - Localized yielding and strain hardening is permitted
  - Ultimate stress is the limit for the local c/s in the connection zone

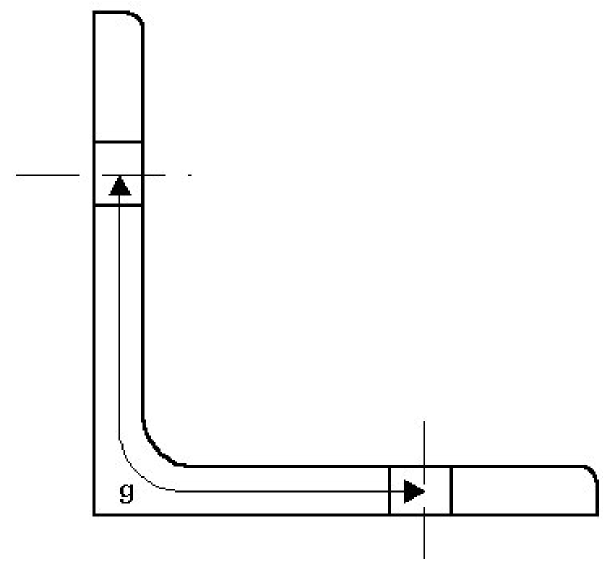
$$AB = \ell_{AB} - d$$

$$AT = \ell_{AB} - 2d + \frac{s^2}{4g} \qquad A_{net} = \min\{AB, AT\}.t$$

d = hole diameter   t = plate thickness



(a) Staggered holes



(b) Angle with hole in both legs

Figure 7 Determination of the net area

Plate in Tension with Bolts

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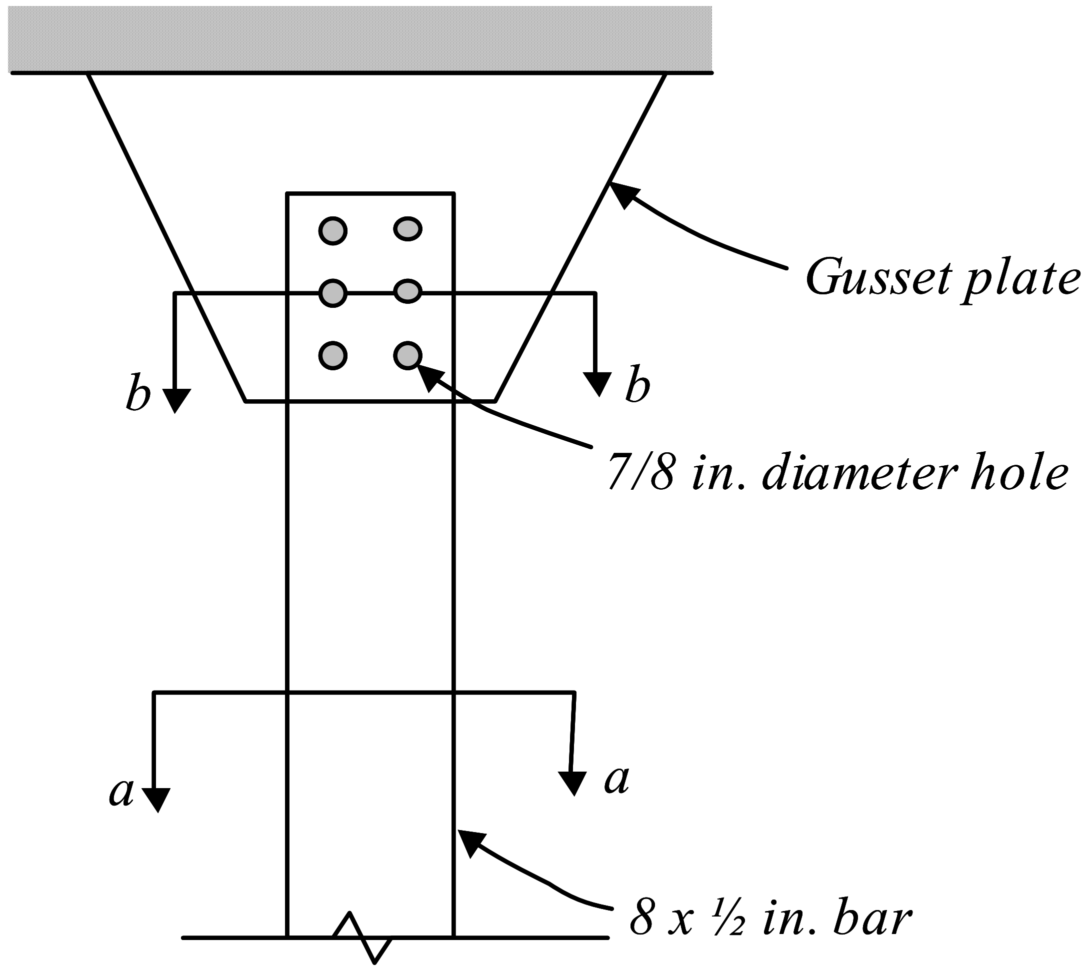
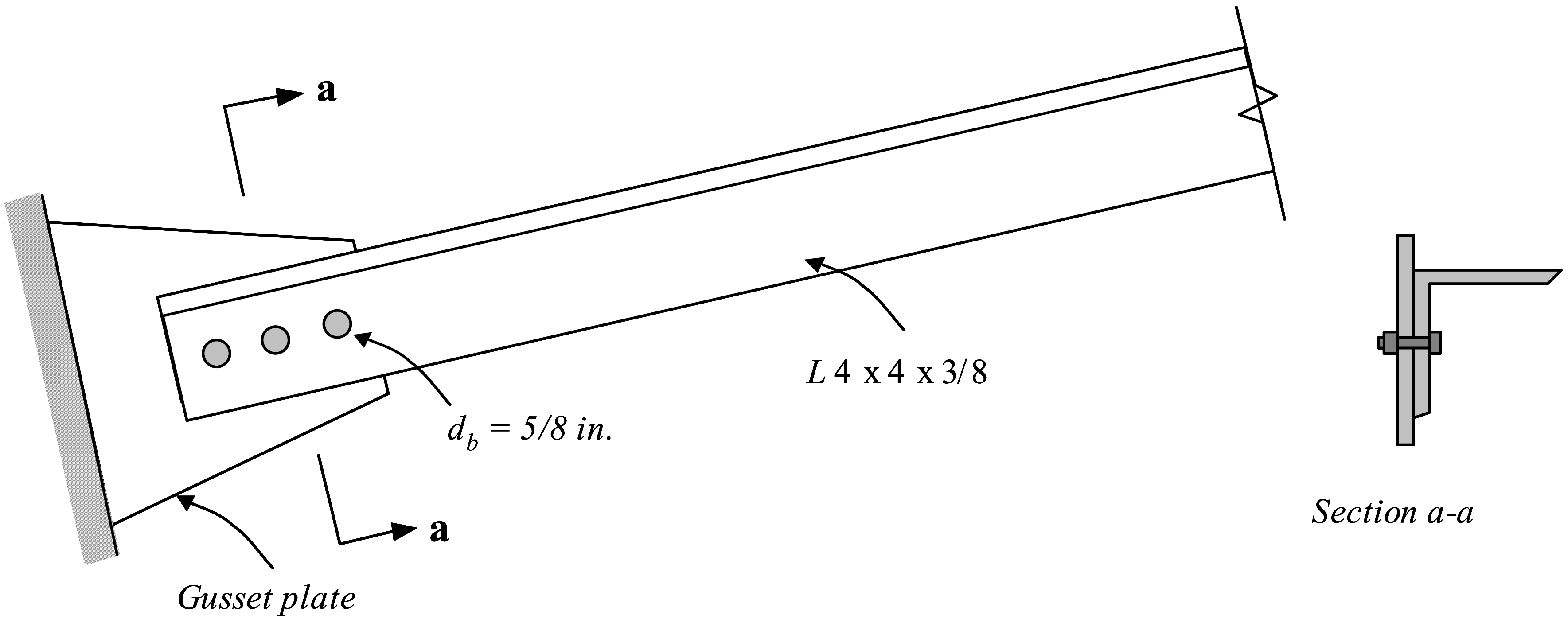
Plate in Tension with Bolts



Section b-b

Section a-a

Angle in Tension with Bolts



Rupture of net section

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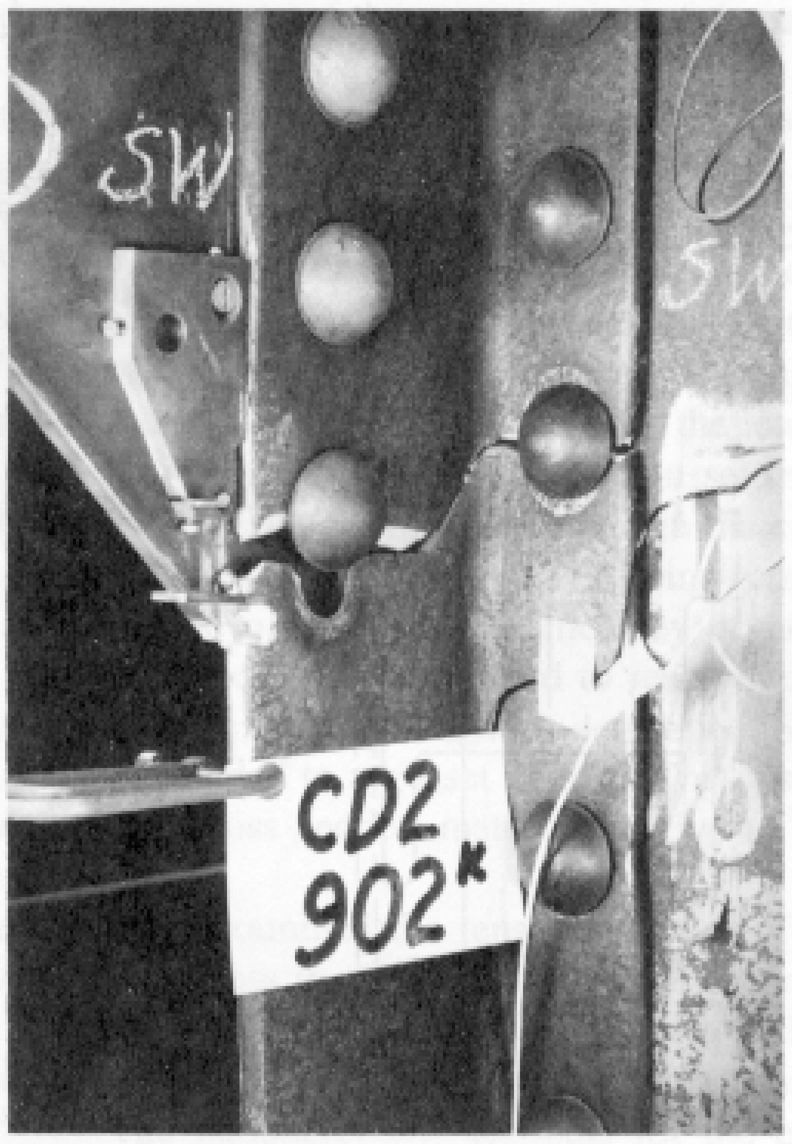

Fig. 6.3. Angle failure in built-up section. (Courtesy of University of Illinois.)

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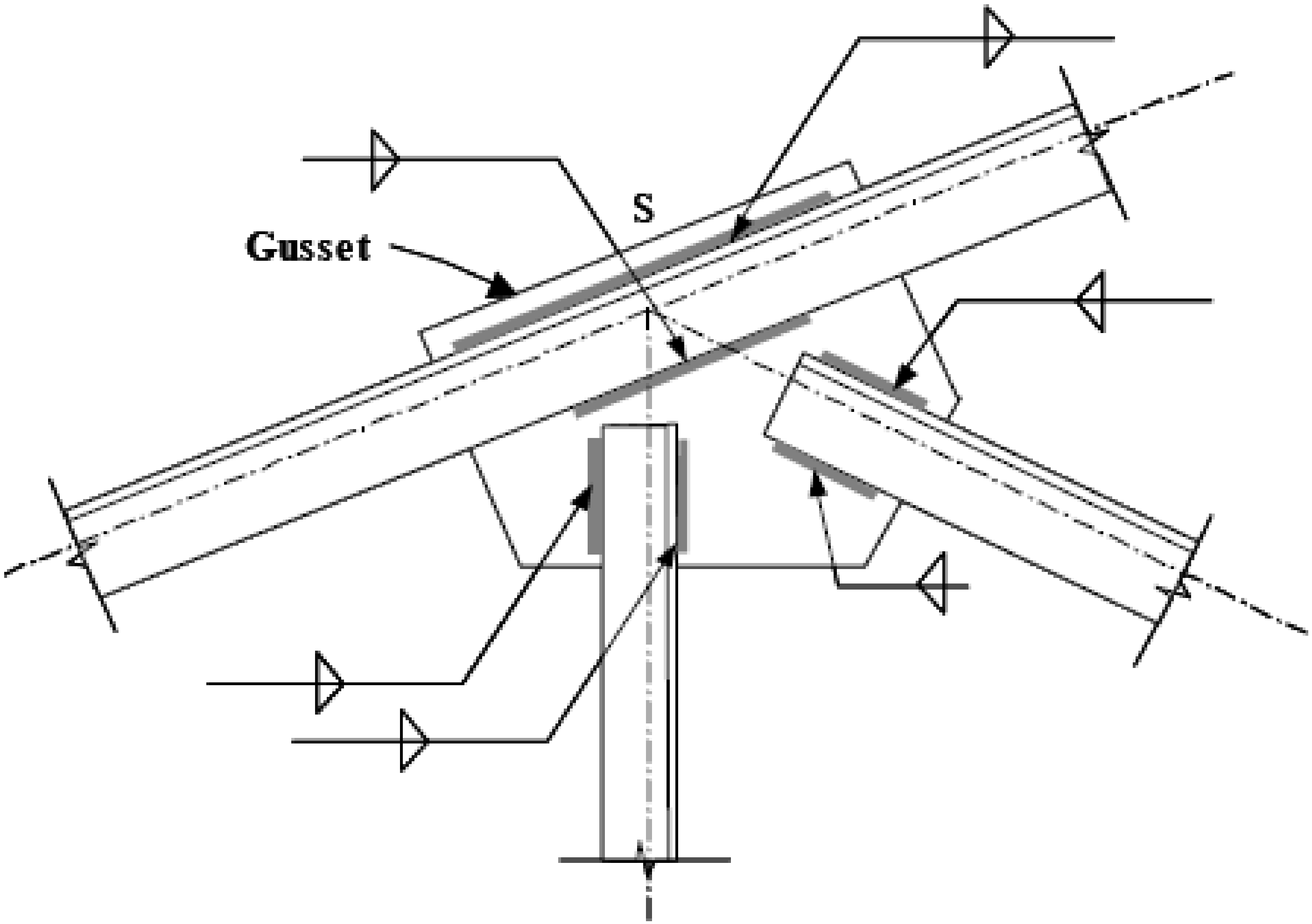
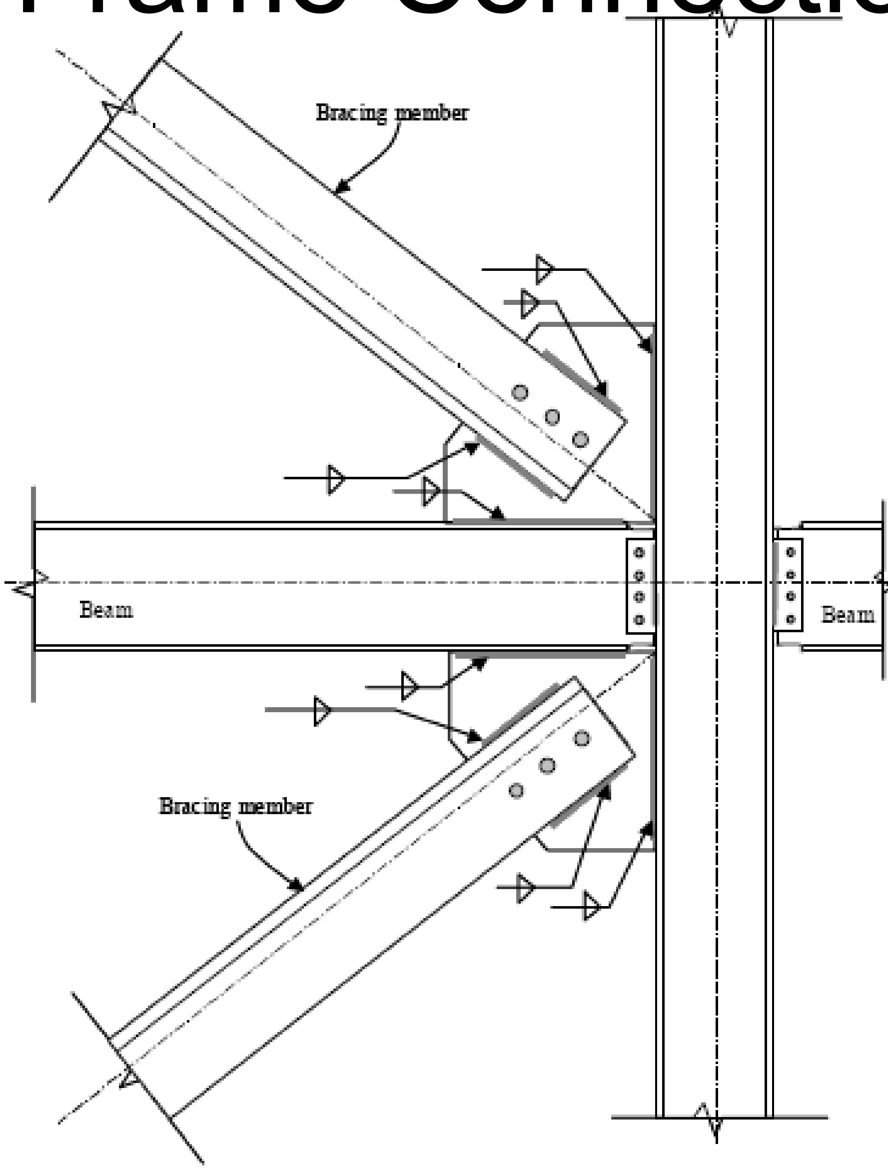
Typical Truss Connection

- 

Typical Frame Connection



Shear lag

- Out-standing parts of rolled sections
  - Legs of angles, flanges, etc.
- Connected parts due to insufficient load transfer in the connection zone
  - Single side welds
  - Two side welds of insufficient lengths
- Cl.12 (effective net areas)

Shear lag

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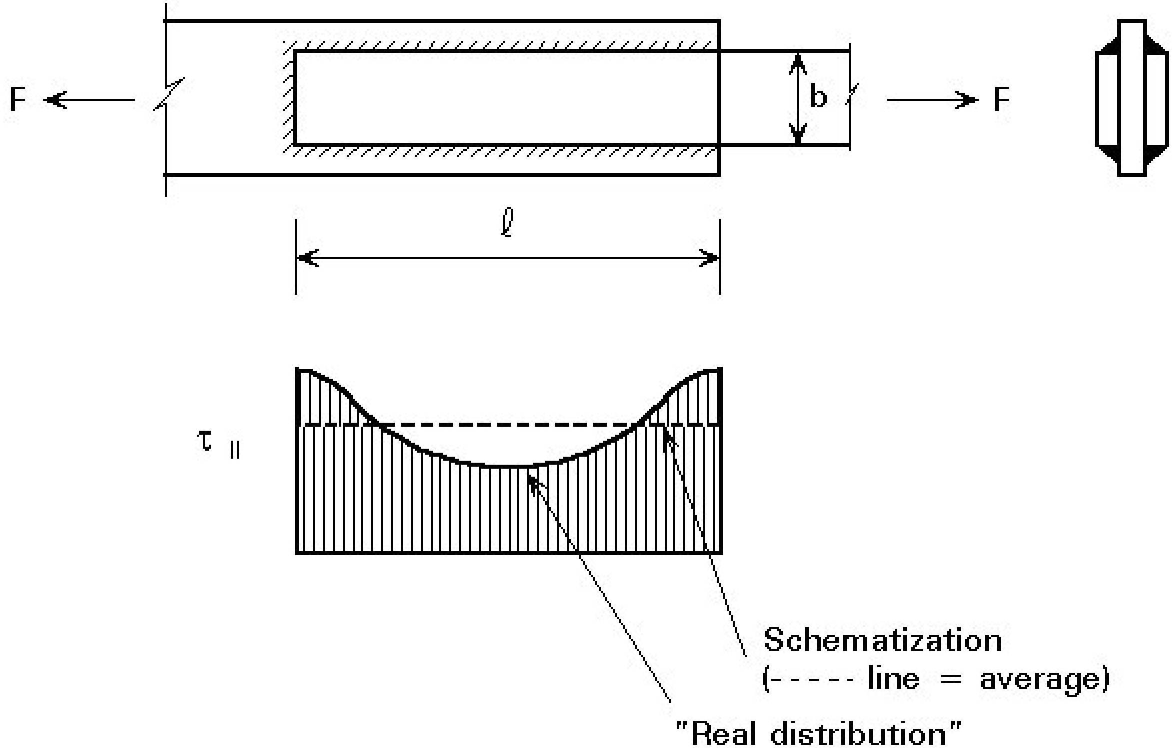

Figure 4a Uneven distribution of shear stress $\tau_{||}$ in a connection with long side fillet welds

Shear lag

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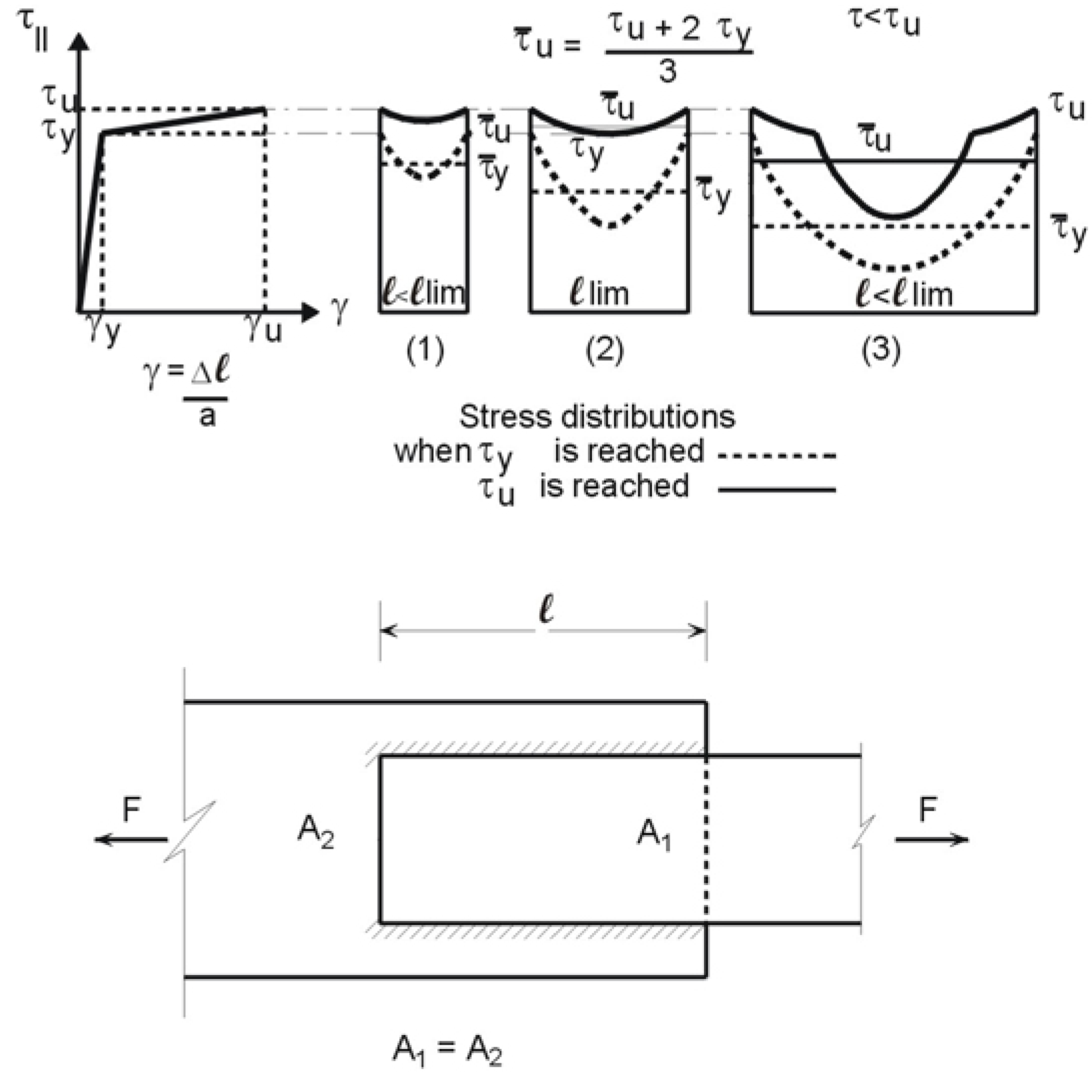

Figure 5 Calculated stress distributions when τ_y and τ_u are reached

Shear lag effect

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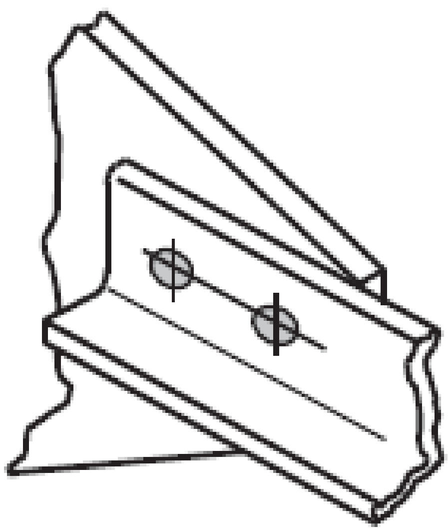
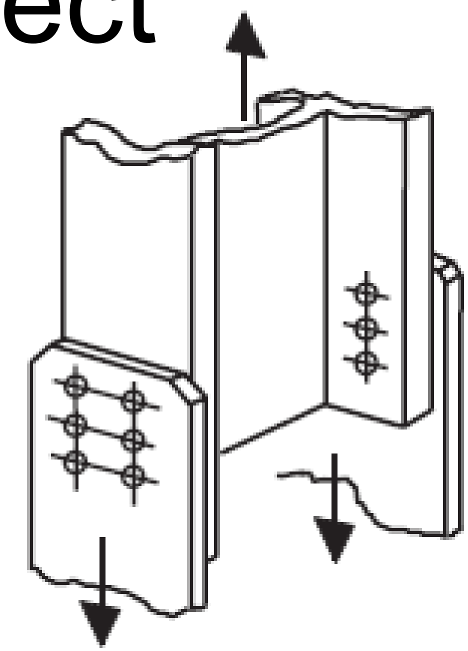
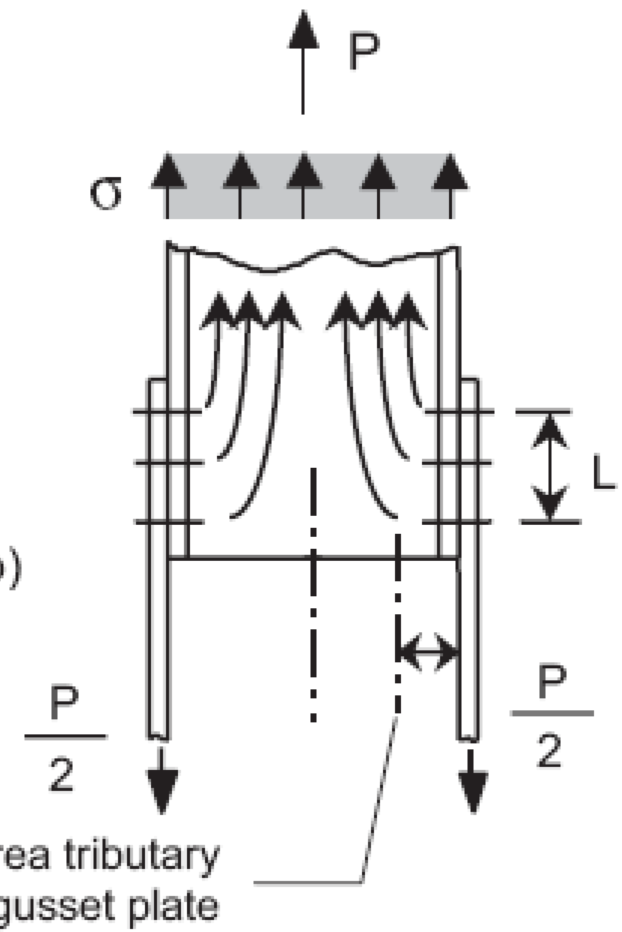


Shear Lag in Angle Connection



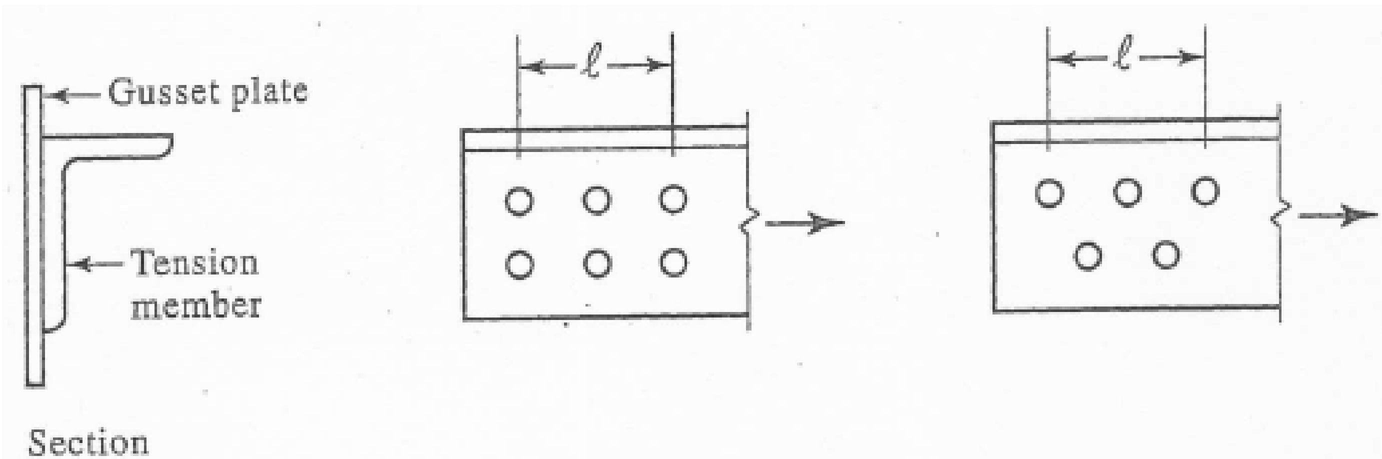
(a)

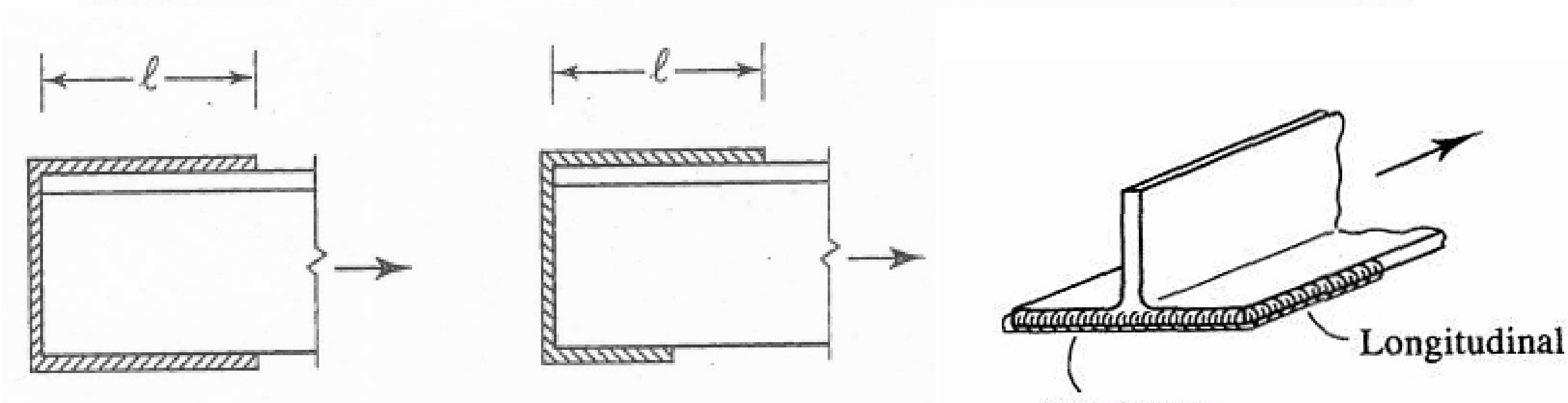
(b)



Shear Lag in Gusset Plate Connection

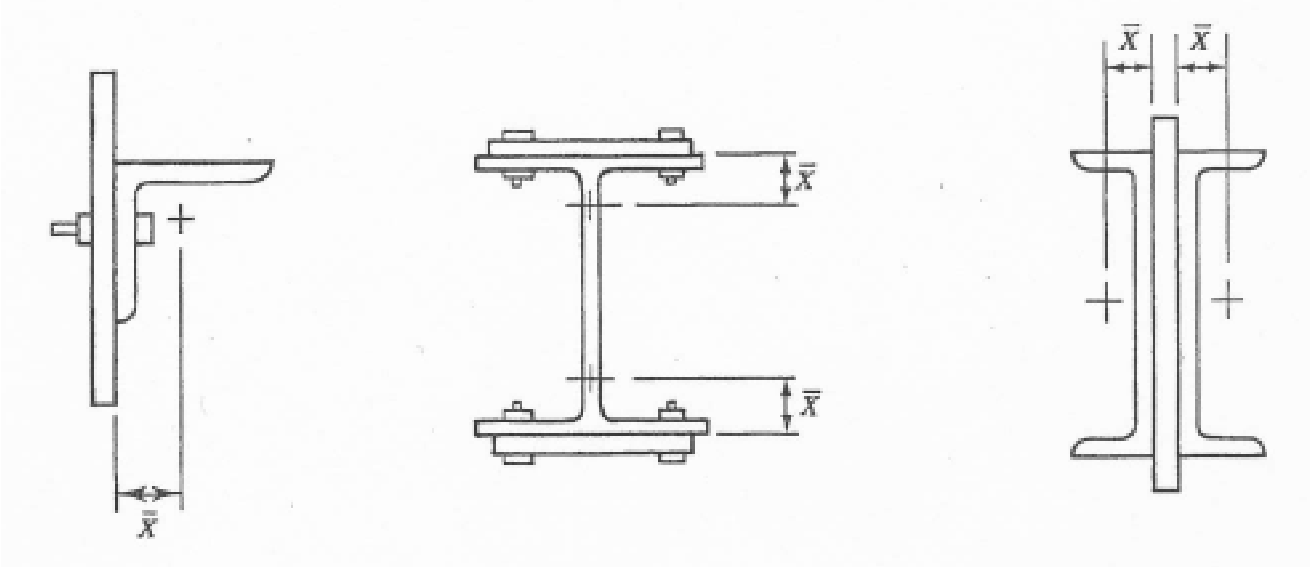
Length of connection (for shear lag)

- 



(b) Welded

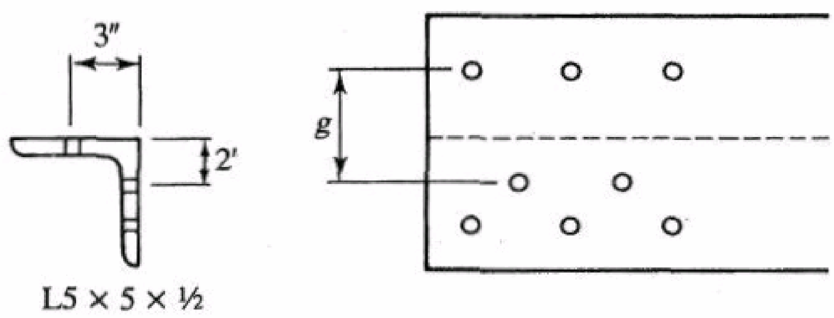
Eccentricity of elements

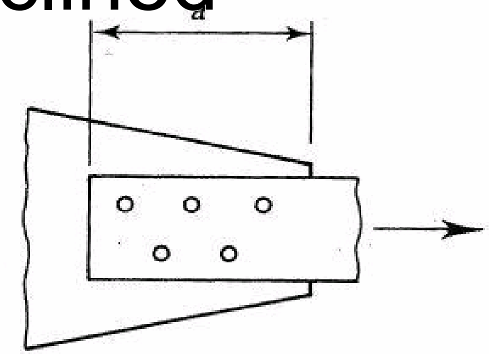
- 

$\bar{x}$ for Various Connections

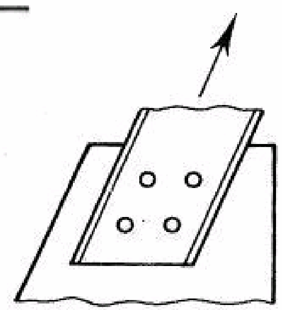
Staggered bolts

- Tear out paths can be inclined
  - $s^2/4g$ rule (Cl. 12)

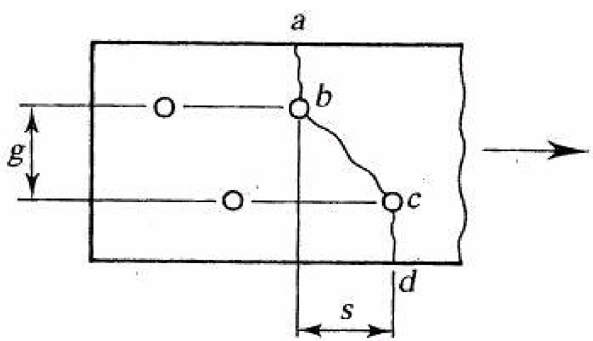




(a)

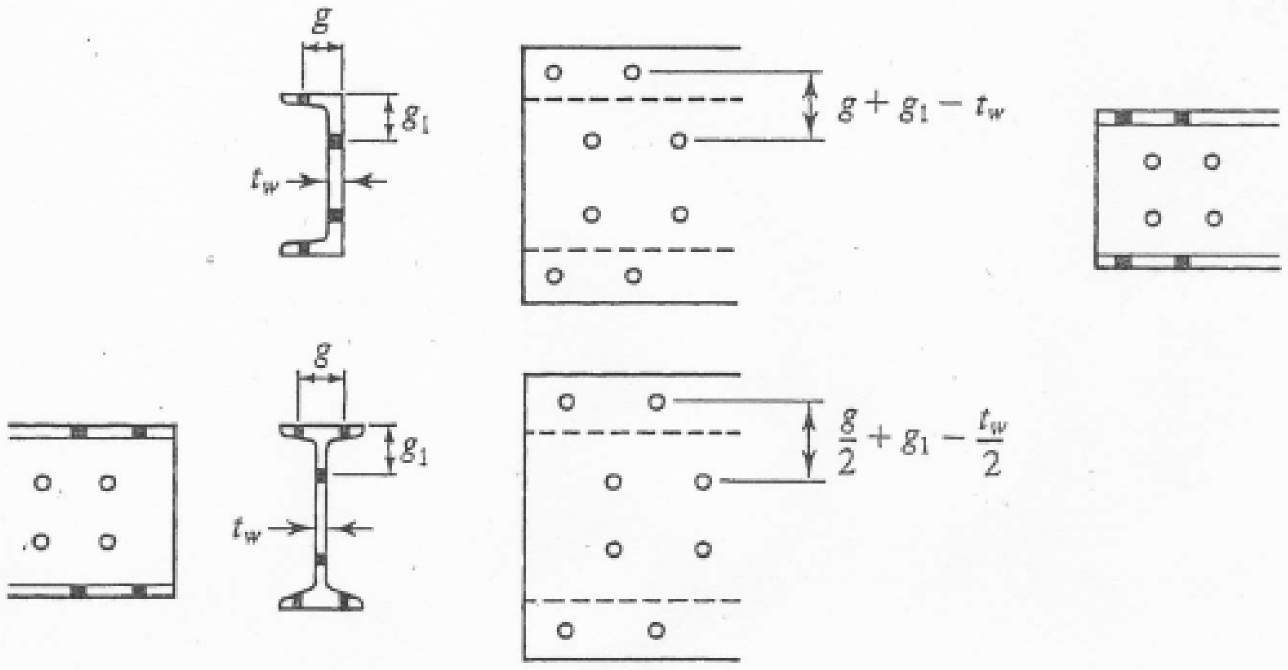


(b)



(c)

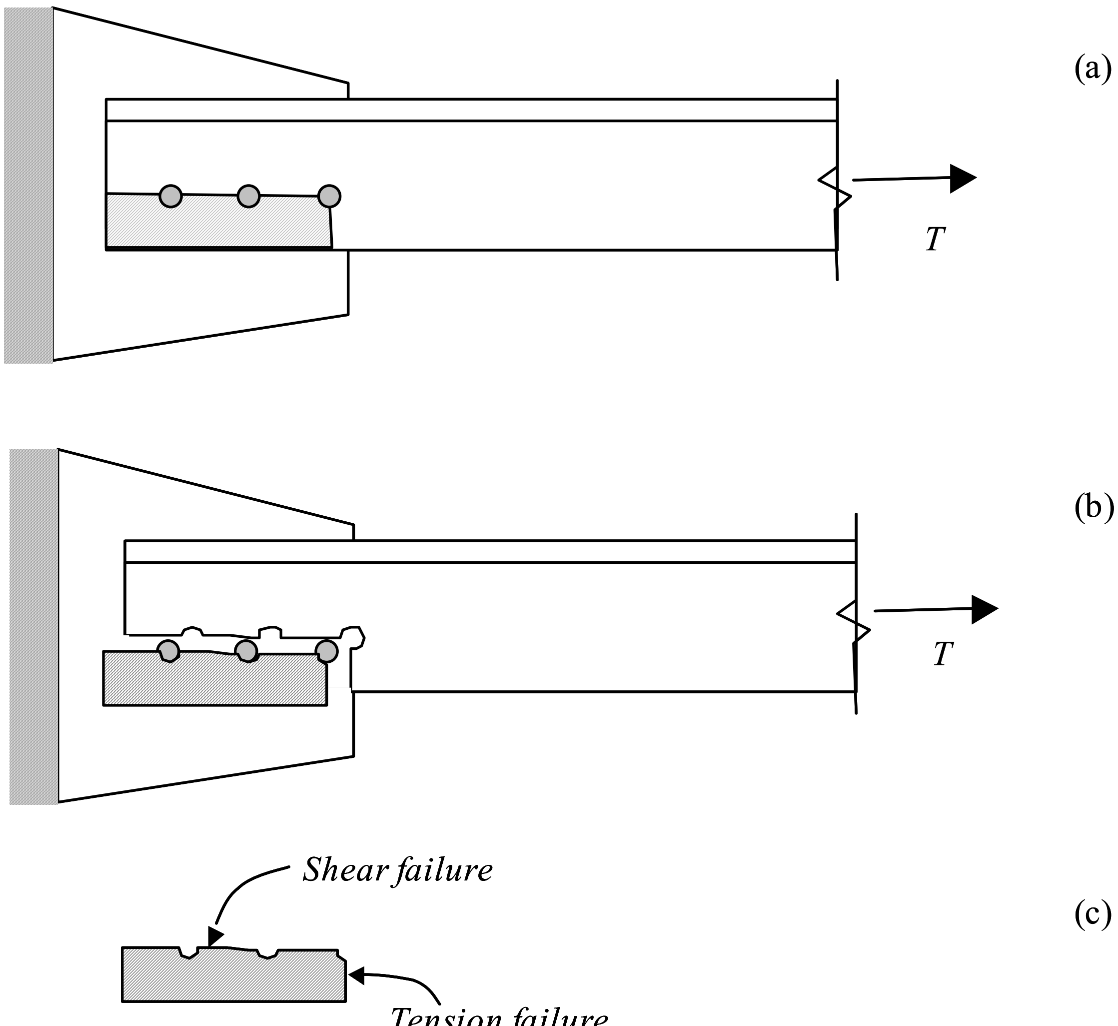
Gauge Length



Gage Length for Folded Sections

Block Shear Tear-out

- Cl. 13.11
- Paths parallel to load



Block Shear Tear-out

- Cl. 13.11
- Paths parallel & perpendicular to load