METALLIC STRUCTURES

TENSION MEMBERS

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TOPICS

- INTRODUCTION
- BEHAVIOR OF TENSION MEMBERS
- CROSS SECTION TYPES
- STIFFNESS LIMITATION
- ALLOWABLE STRESSES
- ACTUAL STRESSES
- STEPS OF DESIGN
- EXAMPLES
- LOAD COMBINATIONS

INTRODUCTION

- Tension Members are those subjected to PURE TENSION forces.
- The most simple member to design.
- No Stability Problems.
- To Design a tension member ⟹ $f_{act} \leq f_{all}$

  Select appropriate cross section area sop that the actual stress is less than the allowable stress
- A stiffness limit is set by codes to limit sagging and reduce vibration effects on slender members.
- Applications ⟹ Truss members, hangers, …

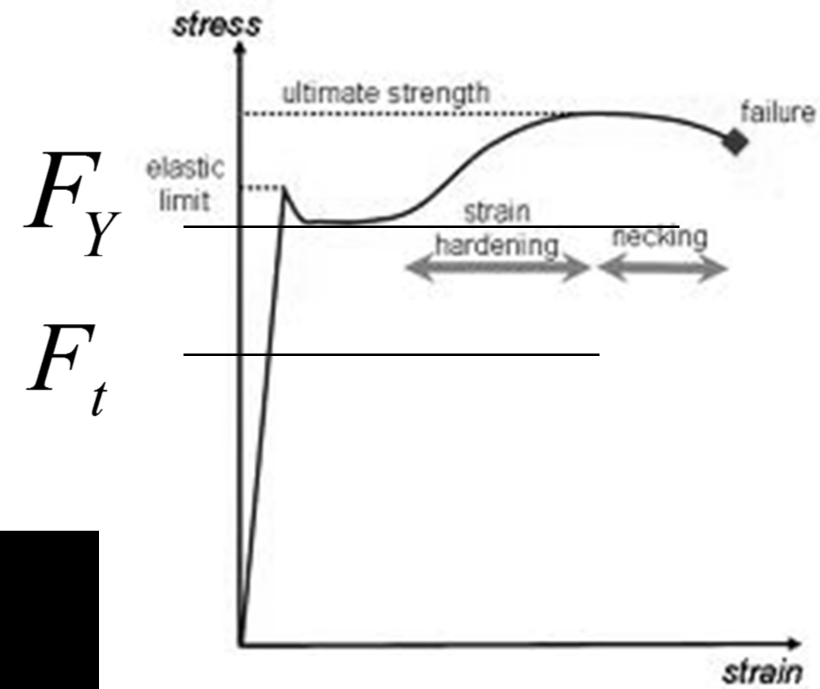
BEHAVIOR OF TENSION MEMBERS

- For CONCENTRIC tension forces, the resulting stress is a uniform stress equally distributed over the member area.

$$f_{act} = \frac{T}{A}$$

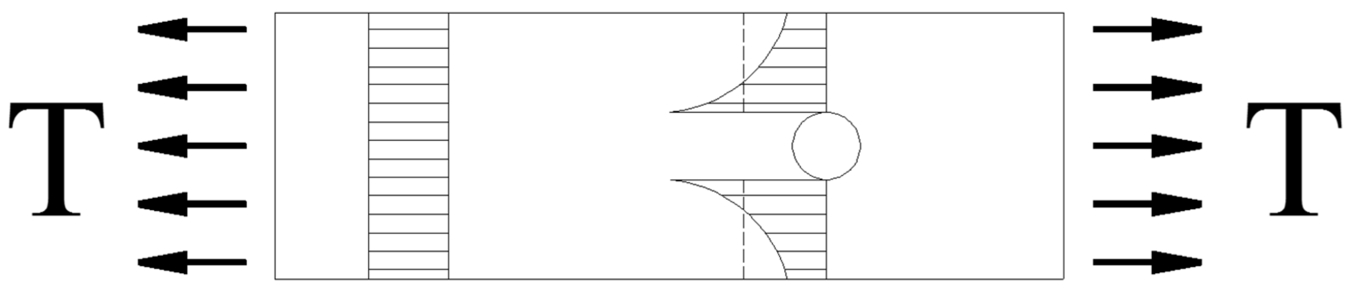
- The actual stress increases with the increase of the load according to the stress strain relationship

$$F_t = \frac{F_Y}{F.S.}$$



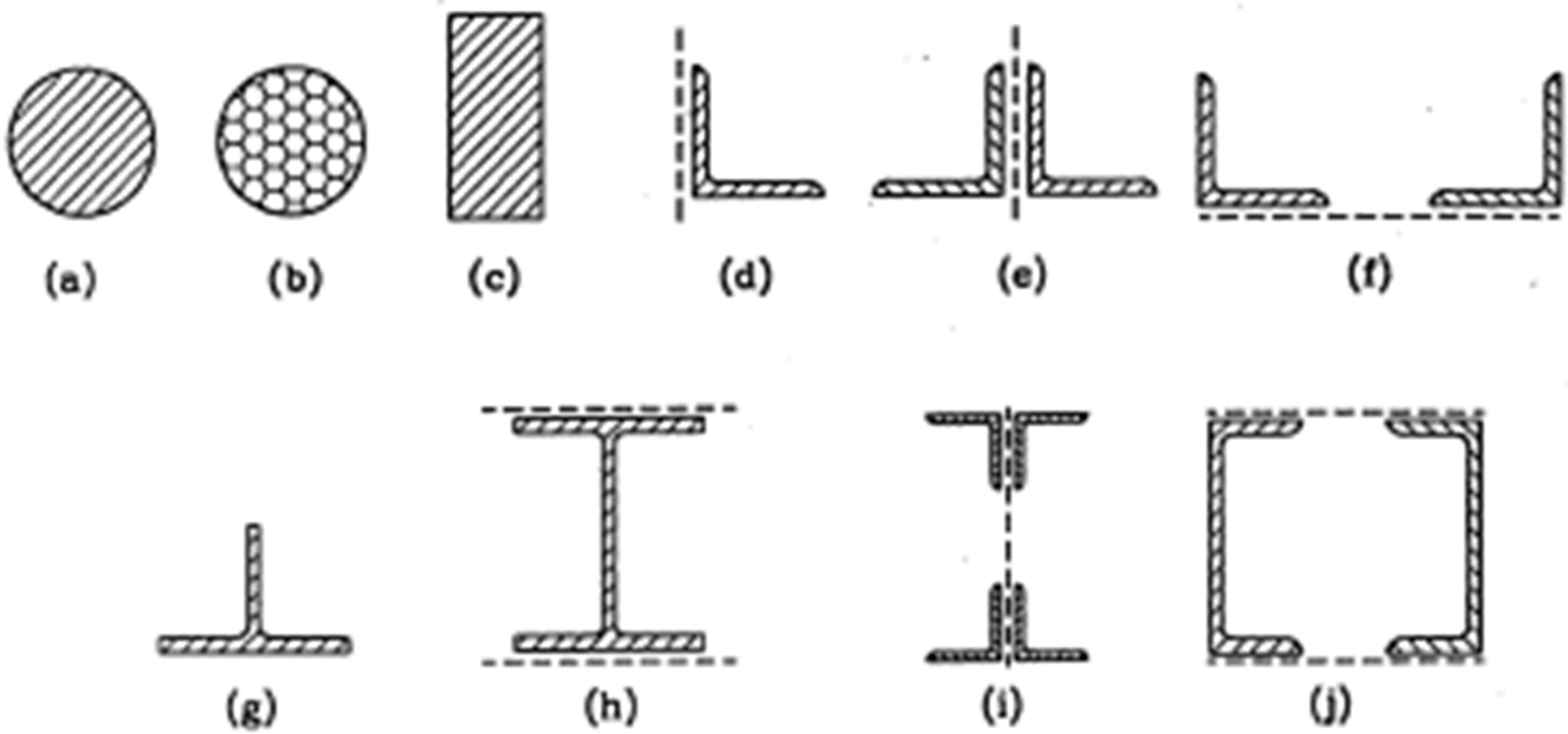
BEHAVIOR OF TENSION MEMBERS

- Stress Concentration due to holes



$$f_g = \frac{T}{A_g} \qquad f_n = \frac{T}{A_n} \qquad f_{\max} \cong 2-3 f_{net}$$

CROSS SECTION TYPES



STIFFNESS LIMITATION

$$\frac{L}{i_{\min}} \leq 300 \qquad i = \sqrt{\frac{I}{A}}$$

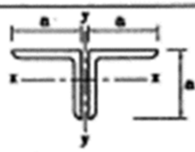
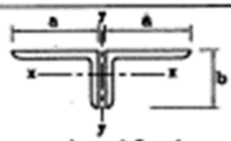
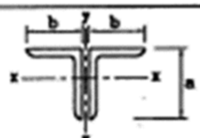
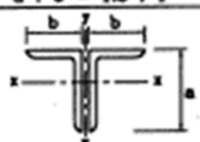
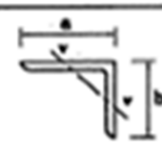
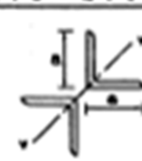
Where,

L = geometric length of member

i_{min} = minimum radius of gyration of member shape

	Members	λ_{max}
Buildings	Tension members	300
Bridges	Tension members in railway bridges	160
	Tension members in railway bridges	180
	Vertical Hangers	300
	Bracing Systems	200

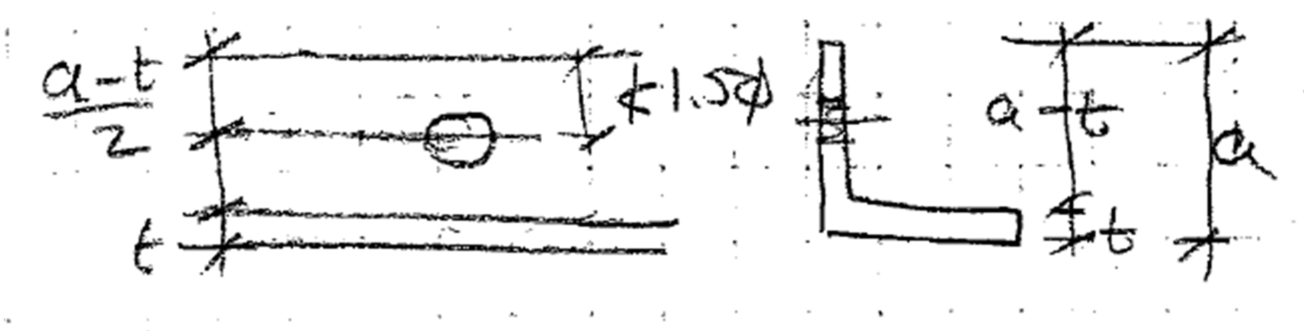
STIFFNESS LIMITATION

CASE	SECTION OF MEMBER	i_x or i_v	i_y or i_u
1		$i_x = 0.3\ a$	--
2	 a : b = 1.5 : 1	$i_x = 0.28\ b$	$i_y = 0.48\ a$
3	 a : b = 1.5 : 1	--	$i_y = 0.3\ a$
4	 a : b = 2 : 1	--	$i_y = 0.3\ a$
5		$i_v = 0.2\ a$	--
6	 a : b = 1.5 : 1	$i_v = 0.14\ a$	--
7	 a : b = 2 : 1	$i_v = 0.1\ a$	--
8		$i_v = 0.385\ a$	--

CONSTRUCTION CONDITION

- To allow for proper installation and tightening of bolts (use only in bolted connections).

$$a - t \geq 3d_b$$



ALLOWABLE STRESSES

- Case I Loading (Main Loads)

$$F_t = \frac{F_Y}{F.S.} = 0.58\ F_Y$$

Steel Grade	**F_Y (t/cm²)**	**F_t (t/cm²)**
St. 37	2.4	1.4
St. 44	2.8	1.6
St. 52	3.6	2.1

- Case II Loading (Secondary Loads)

Increase allowable stresses by 20%

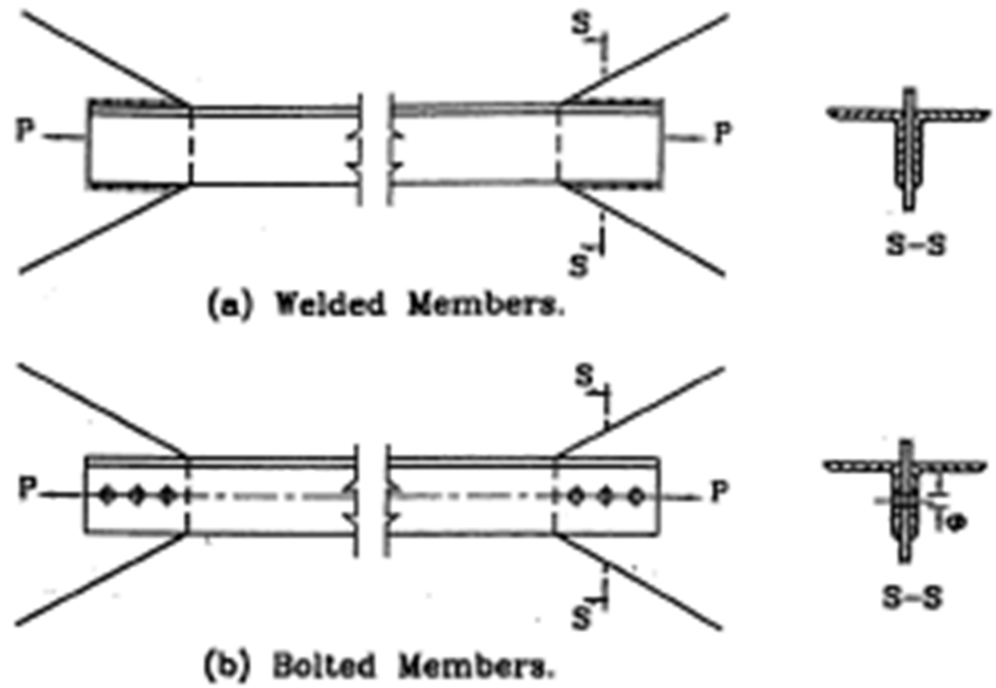
ACTUAL STRESSES

- Welded Connection

$$f_{ta} = \frac{T}{A_g}$$

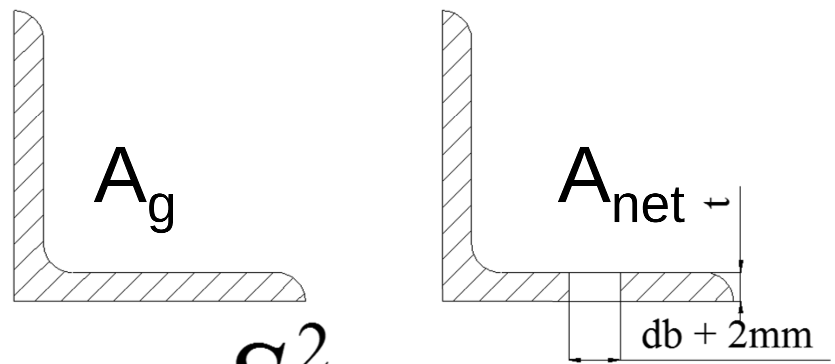
- Bolted Connection

$$f_{ta} = \frac{T}{A_{net}}$$

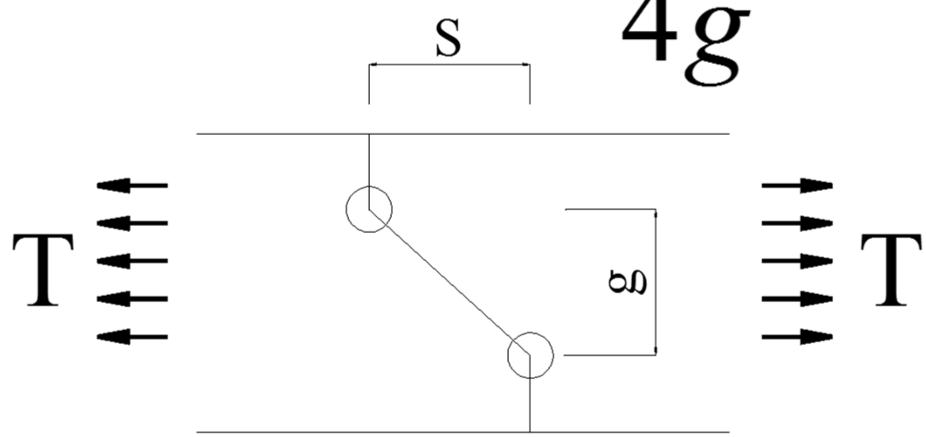


ACTUAL STRESSES

$$A_{net} = A_g - t_L \times (d_b + 2mm)$$



$$A_{net} = A_g - t \times d_h \times n_b + t \times \frac{S^2}{4g} \times n_l$$

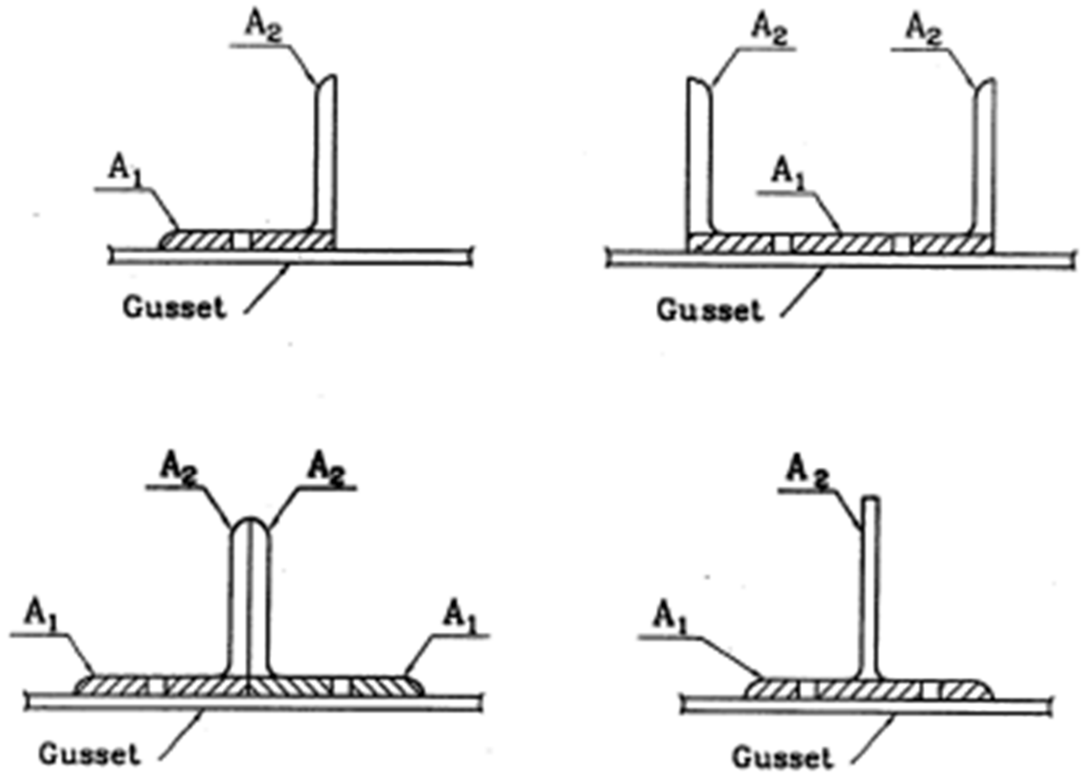


ACTUAL STRESSES

- For Eccentrically Loaded Members

$$A_{eff} = A_1 + RF \times A_2$$

$$RF = \frac{3A_1}{3A_1 + A_2}$$



DESIGN STEPS

- Determine
  - DF (tension Force), Load Case (I or II)
  - Member location, Length (L_g), Bolted or Welded
- Choose section type (1L, 2L back to back, 2L star shape). Then get i_{min} (0.2a, 0.3a, 0.385a)
- Stiffness condition (get minimum "a")
- Construction condition (bolted), (get minimum "a-t")
- Obtain an approximate area

$$A_{app} = \frac{DF}{0.58F_Y \times 0.85 \times 0.75 \times 1.2}$$

0.85 (net area if bolted), 0.75 (effective area if unsymmetric), 1.2 (if caseII)

DESIGN STEPS

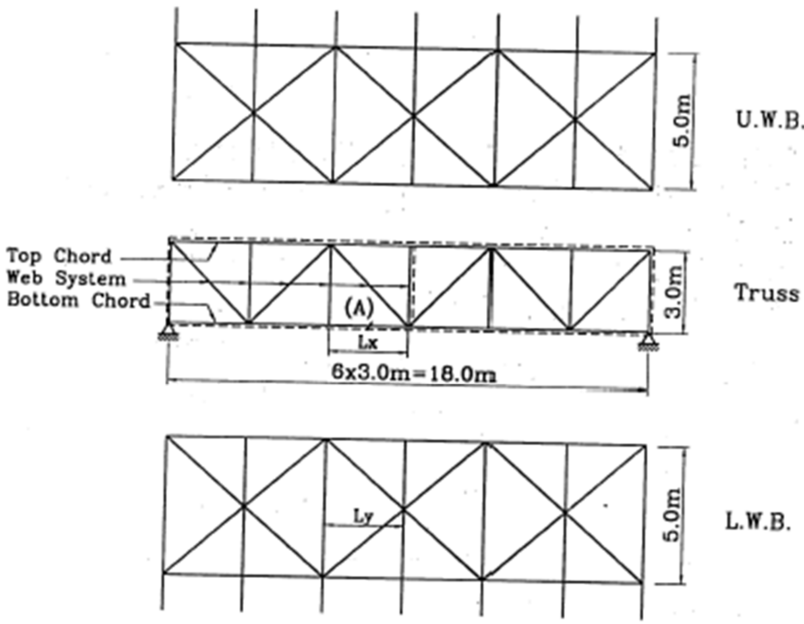
- Choose a suitable section from tables
  - Use minimum "a"
  - Use A_{app}
- Check of Safety
  - Actual Stress
  - Allowable Stress

$$f_{ta} = \frac{T}{A_{net,eff}} \qquad f_{ta} \leq F_t$$

EXAMPLES

Example (2.1):

Design the lower chord tension member (A). Design force = 30.0 tons (Case of loading II) ometric length of the member is 300 cms (ϕ = 16 mms for bolted connections.



Solution

Type of Cross - Section:

- The member being a bottom chord member, choose 2 $<^s$ back to back.
- Buckling lengths; $L_x = L_y$ = 3.0 ms, choose 2 $<^s$ with equal legs.

Stiffness Condition:

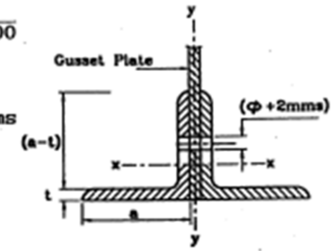
$l_x / i_x \le 300$ $\quad \therefore a \ge \frac{300}{0.3 \times 300}$

(tension member).

$i_x = 0.3\, a$ (2 $<^s$ $\quad \therefore a \ge 3.33$ cms

(back to back equal legs)

See Table 2.1



*** Bolted Connection**

. **Construction Condition:**

(a-t) < 3 ϕ < 4.80 cms

. **Required Cross - Section:**

(Approximate)

$$A_{req.} = \frac{30.0}{2 \times 1.40 \times 1.2 \times 0.85}$$

(1< gross; 2 $<_s$; all. stress; wind stress; D.F. bolts)

$A_{req.\,1<}$ = **10.50 cm²**

. **Check on Stresses:**

From stiffness & construction conditions and required cross section;

Choose 2 $<^s$ 65x65x9

$A_{1<} = 11.0\ cm^2$

$\therefore A_{net} = 2\left[11.0-(1.60+0.2)\times 0.90\right]$

$= 18.76\ cm^2$

$\therefore f_t = \frac{30}{18.76} = 1.599\ t/cm^2$

*** Welded Connection**

. **no construction condition**

. **Required Cross - Section:**

$$A_{req.} = \frac{30.0}{2 \times 1.40 \times 1.2}$$

(1< gross; 2 $<_s$; all. stress; wind stress)

$A_{req.\,1<}$ = **8.93 cm²**

. **Check on Stresses:**

From stiffness condition and required cross section;

Choose 2 $<_s$ 70 x 70 x 7

$A_{1<} = 9.40\ cm^2$

$f_t = \frac{30}{2 \times 9.40} = 1.595\ t/cm^2$

LOAD COMBINATIONS

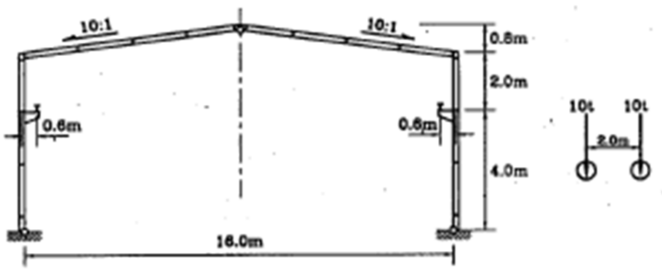
Case of Loading	**Allowable Stress**
Case (I): Dead = Live + Crane Vertical & dynamic effect	f
Case (II): Case (I) + Crane lateral shock + Wind + Earthquake + Temperature + etc..	f*1.2

LOAD COMBINATIONS

__Example (1.1):__ Frame system

For the shown frame system:

- Spacing between frames = 5.0 ms
- Panel = 2.0 ms (spacing between purlins)
- Roof cover = corrugated sheets weighting 15 kgm/m^2
- Own weight of steel = 30 kgm/m^2 of covered area.
- Crane loads : the maximum reaction of Crane concentrated loads 10 tons, each spaced at 2.0 ms.



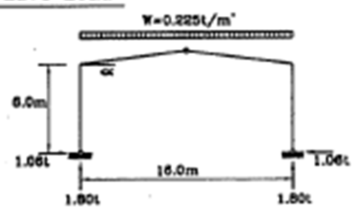
(1) __Dead and Live Load__

* __Dead Loads:__

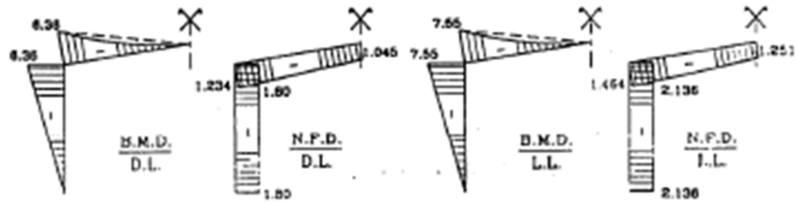
$$W_{D.L.} = W_{o.wt} + W_{cover}$$

$$= 0.03 \times 5 + \frac{0.015}{\cos\alpha} \times 5$$

$$= 0.225 \text{ t/m}'$$



* __Live Loads:__ (Refer to clause 1.5 and Figure (5-1) of E.C.P. of steel constructions 1999)



According to the E.C.P, the roof is inaccessible , $\tan\alpha = 0.1$

$\therefore I_u = 53.33 \text{ kgm/m}^2$

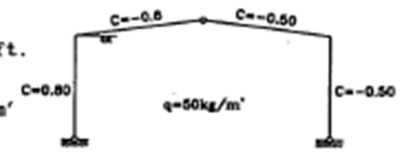
$\therefore W_{11} = 0.053 \times 5 = 0.267 \text{ t/m}'$

(2) __Wind Loads__

Refer to E.C.P. 1999 clause 1.12 item "II"

or to chapter 7 paragraph 7.5

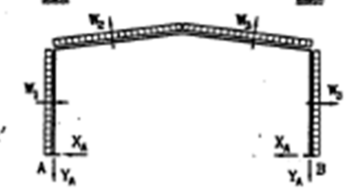
Consider the case of wind left.



$$W_1 = \frac{0.80 \times 50}{1000} \times 5 = 0.20 \text{ t/m}'$$

$$W_2 = \frac{0.60 \times 50}{1000} \times 5 = 0.15 \text{ t/m}'$$

$$W_3 = \frac{0.50 \times 50}{1000} \times 5 = 0.125 \text{ t/m}'$$



$$(+\sum M_B = 0 \quad \therefore (0.2+0.125)x6x3 + (0.125-0.15) \times \frac{8}{\cos\alpha} \times \sin\alpha \times 6.40$$

$$+ 0.125 \times \frac{8}{\cos\alpha} \times \cos\alpha x4 + 0.15 \times \frac{8}{\cos\alpha} \times \cos\alpha x12 - y_A x16$$

$$= 0.0$$

$\therefore y_A = 1.5$ ton

$$\therefore y_B = (0.125 + 0.15) \times \frac{8}{\cos\alpha} \times \cos\alpha - y_A$$

$= 0.7$ ton

$$(+\sum M_c \text{ (right)} = 0 \quad \therefore 0.125 \times \frac{8}{\cos\alpha} \times \frac{4}{\cos\alpha} + 0.125 \times 6 \times 3.80$$

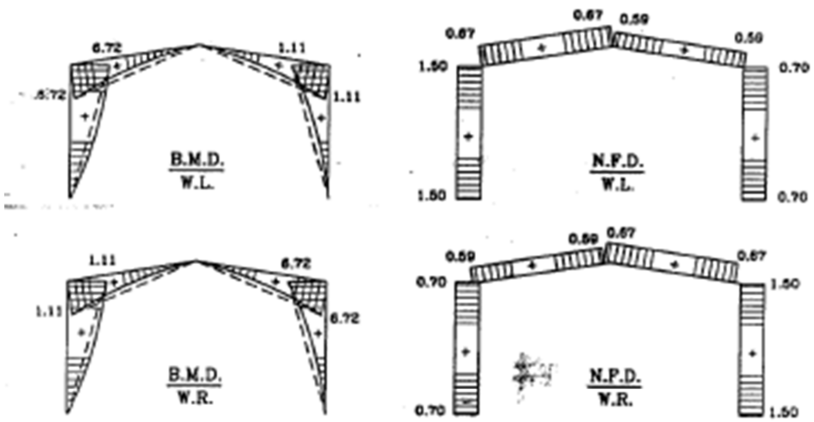
$$- 0.7 \times 8 = X_B x6.80$$

$\therefore X_B = 0.19$ ton

LOAD COMBINATIONS

$(+\sum M_c \text{ (left)} = 0 \quad \therefore X_A = \frac{1}{6.80}\left[-0.15 \times \frac{8}{\cos\alpha} \times \frac{4}{\cos\alpha} + 0.20 \times 6 \times 3.80 + 1.5 \times 8\right]$

$\therefore X_A = 1.72$ ton



(3) Crane Loads

Refer to E.C.P. 1999 clause 1.9

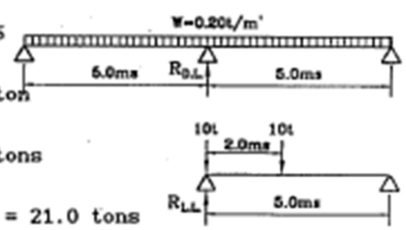
$V_{max} = R_{D.L} + R_{L.L} \times 1.25$

$R_{D.L} = 0.20 \times 5.0 = 1.0$ ton

$R_{L.L} = 10 + 10 \times \frac{3}{5} = 16$ tons

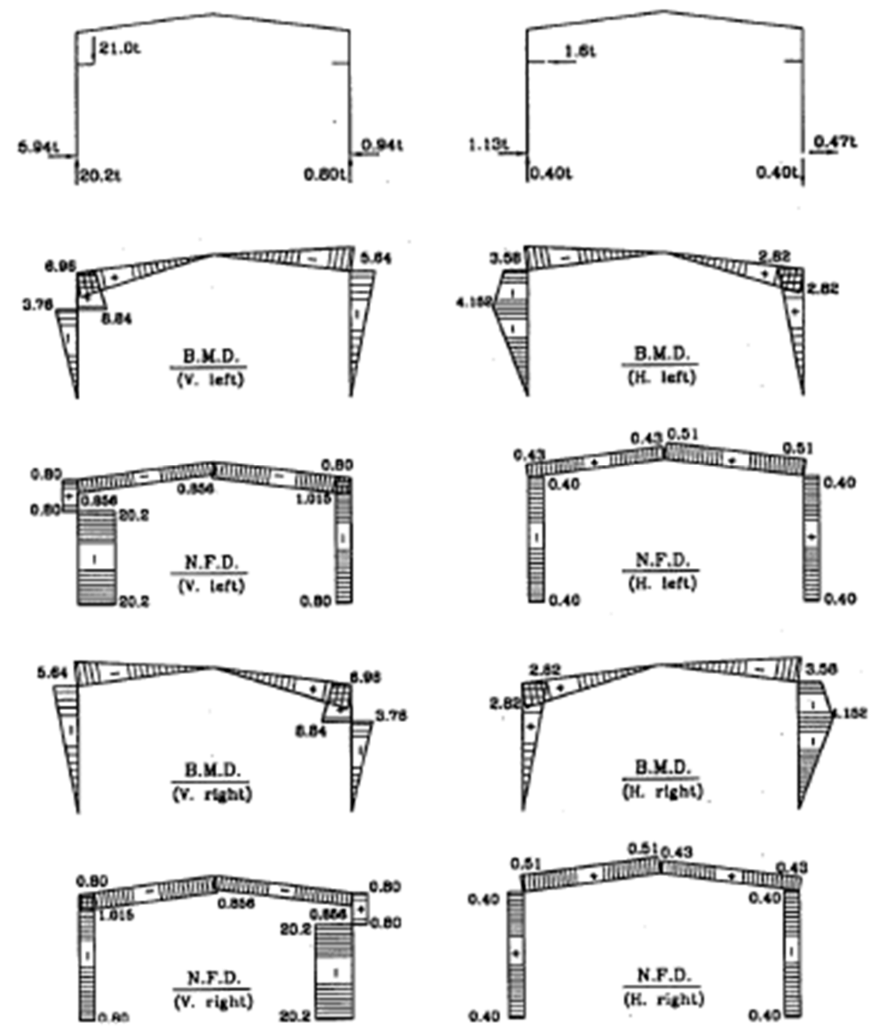
$\therefore V_{max} = 1 + 16 \times 1.25 = 21.0$ tons

$\therefore H = 0.10 \times R_{L.L} = 0.10 \times 16 = 1.60$ ton



To take into acount the dynamic effect of the electrical overhead crane the live load is to be increased by 25% according to E.C.P. 1999 clause 1.9 - (i.e. $R_{L.L}$ is to be multiplied by 1.25)

Cases of Vertical Crane Reaction (V) | Cases of Lateral Shock Reaction (H)



LOAD COMBINATIONS

Sec.		D.L.	L.L.	Crane Left			Crane Right			Wind		Max. M		Max. N	
				V	H ←	H →	V	H ←	H →	Left	Right	+ve	−ve	+ve	−ve
1	M	0	0	0	0	0	0	0	0	0	0	--	--	--	--
	N	−1.80	−2.14	−20.2	−0.40	0.40	−0.80	0.40	−0.40	1.50	0.70	--	--	--	−24.14 (I)
2	M	−4.24	−5.03	−3.76	−4.52	4.52	−3.76	4.52	−4.52	4.30	0.90	0.82 (II)	−17.55 (II)	--	−13.03
	N	−1.80	−2.14	−20.2	−0.40	0.40	−0.80	0.40	−0.40	1.50	0.70	−20.63	−24.54	--	−24.14 (I)
3	M	−4.24	−5.03	8.84	−4.52	4.52	−3.76	4.52	−4.52	4.30	0.90	13.42 (II)	−13.03 (I)	13.42	−13.03
	N	−1.80	−2.14	0.80	−0.40	0.40	−0.80	0.40	−0.40	1.50	0.70	0.37	−4.74	0.37 (II)	−4.74 (I)
4	M	−6.36	−7.55	6.96	−3.58	3.58	−5.64	3.58	−3.58	6.72	1.11	10.90 (II)	−19.55 (I)	9.44	−19.55
	N	−1.80	−2.14	0.80	−0.40	0.40	−0.80	0.40	−0.40	1.50	0.70	0.37	−4.74	0.37 (II)	−4.74 (I)
5	M	−6.36	−7.55	6.96	−3.58	3.58	−5.64	3.58	−3.58	6.72	1.11	10.90 (II)	−19.55 (I)	--	−19.55
	N	−1.234	−1.464	−0.86	0.43	−0.43	−1.015	−0.43	0.43	0.67	0.59	−2.154	−3.713	--	−3.71 (I)