Design of Machines and Mechanical Systems (PC-BTM711)

Session 24

Module 6: Design of EOT Crane

Session Outcomes

- Perform design calculations for
  - Snatch block assembly
  - Rope drum assembly
  - Overhead trolley design

Loading to be considered in design

- Normal service
- Normal service with wind
- Crane out of service condition
- Exceptional loading
  - Testing
  - Erection and commissioning
  - Collision

Loads for Normal Loading condition, R_N

- **Structural parts**

$$R_N = Max(R_d + R_h + R_m + R_f, R_d + R_{hi})$$

R_d = Dead weight

R_h = Hook load (Safe Working Load, SWL)

R_m = Dynamic load from acceleration/braking

R_f = Frictional forces

R_{hi} = Hook load increased by impact factor

- **Rope design**

$$R_N^{rope} = R_d + R_h + R_m + R_f$$

QUIZ

Loads for Normal Condition

Which of the following is NOT to be considered for to calculate design load during normal loading condition of ROPE?

1) Load due to acceleration of object being lifted

2) Impact loading

3) Both of the above

Allowable stresses (IS 3177)

- Applicable to all structural parts except wire ropes

$$Permissible\ stress, F_s = \frac{UTS}{C_{df} C_{bf} C_{sf}}$$

C_{df} = duty/impact factor from DDB T27.2

C_{bf} = basic stress factor = 3.15 for normal loading

C_{sf} = safety factor = 1.12 for mild steel

Allowable Stress Factors (IS-3177)

Table 3 Values of Co-efficient, C_{bf}
(*Clause* 7.4.3)

Case of Loading	I	II	III and IV
C_{bf}	3.15	2.5	2.0

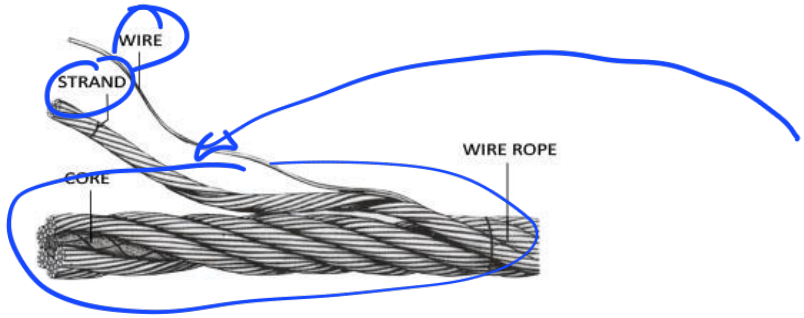
Table 4 Values of Co-efficient, C_{sf}
(*Clause* 7.4.3)

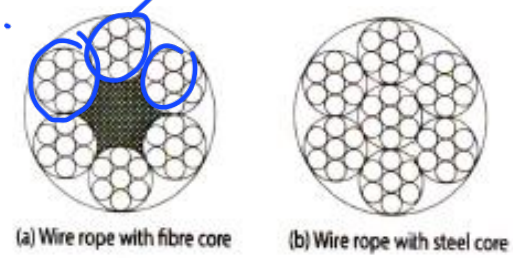
For ordinary grey cast iron or for cast or forged components where blow holes or internal cracks can not be detected.	1.25
For mild steel Fe 310 and Fe 410	1.12
For other materials Fe 44 and Fe 57, etc.	1.00

Allowable stresses (IS 3177)

- Pure tension : $1.25 f_t < F_s$
- Pure compression : $f_c < F_s$
- Pure shear : $\sqrt{3} f_s < F_s$
- Tension+bending+shear: $\sqrt{(1.25 f_t + f_{bt})^2 + 3 f_s^2} < F_s$
- Compr.+bending+shear : $\sqrt{(f_c + f_{bc})^2 + 3 f_s^2} < F_s$

Construction of wire rope



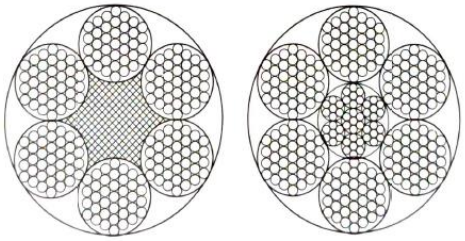


(a) Wire rope with fibre core (b) Wire rope with steel core

- Made from cold drawn and specially heat-treated steel wires with UTS = 1300-2000 Mpa
  - Fiber and steel core
- Designation
  - 6x19, 6x37, etc.
- Regular and Lang lay
- IS 2266 provide breaking strength of wire ropes

Tensile designation	Range of tensile strength (N/mm^2)
1230	1230–1620
1420	1420–1810
1570	1570–1960
1770	1770–2150
1960	1960–2340

Table 27.11 *Breaking load and mass for 6 × 37 (18/12/6/1) construction wire ropes*

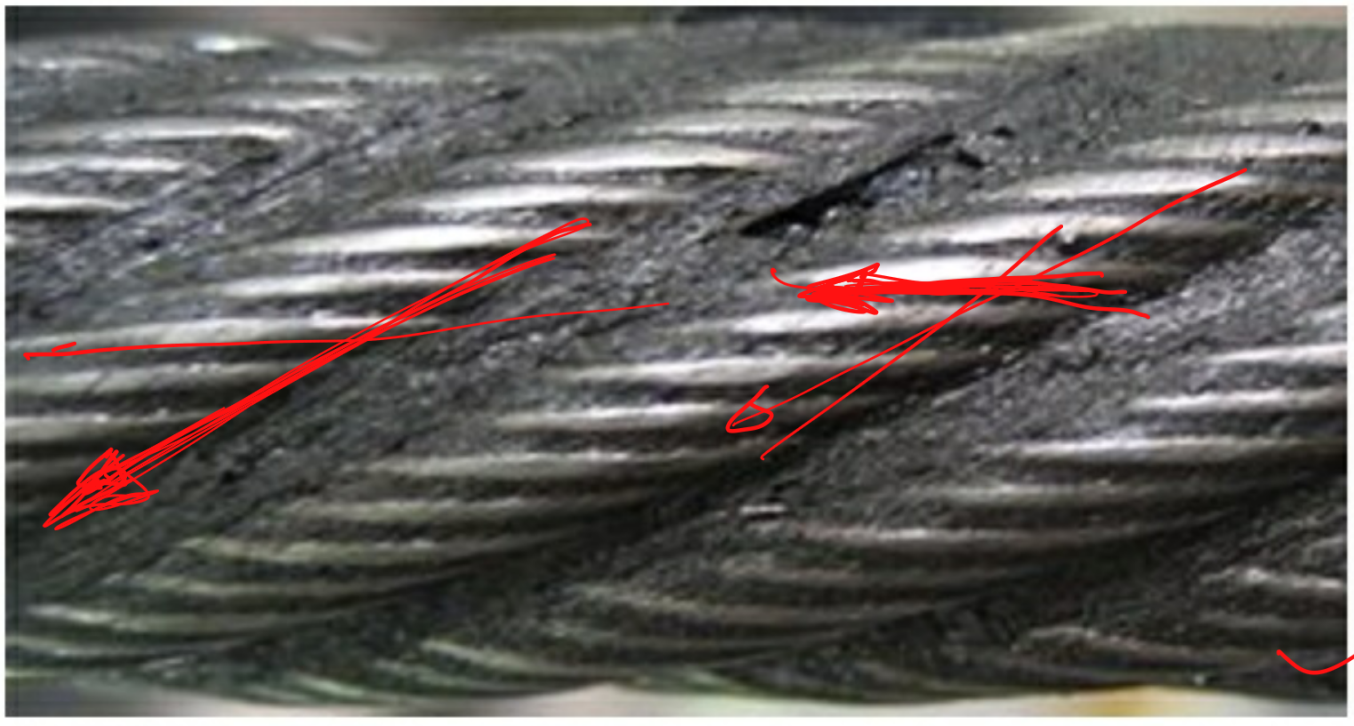


(a) Wire rope with fibre core (b) Wire rope with steel core

Nominal diameter (*d*) (mm)	Approximate mass (kg/100 m)		Minimum breaking load corresponding to tensile designation of (kN)					
			1570		1770		1960	
	Fibre core	Steel core	Fibre core	Steel core	Fibre core	Steel core	Fibre core	Steel Core
8	22.1	24.4	30	32	33	36	37	40
9	28.0	30.8	37	40	42	46	47	51
10	34.6	38.1	46	50	52	56	58	62
11	41.9	46.1	56	60	63	68	78	76

(*Contd.*)

https://sites.google.com/site/designoftransmissionsystems/Design-of-Flexible-Elements/wire-rope



Left-hand ordinary lay (LHOL) wire rope (close-up). Right-hand lay strands are laid into a left-hand lay rope.

Right-hand lang lay (RHLL) wire rope (close-up). Right-hand lay strands are laid into a right-hand lay rope.

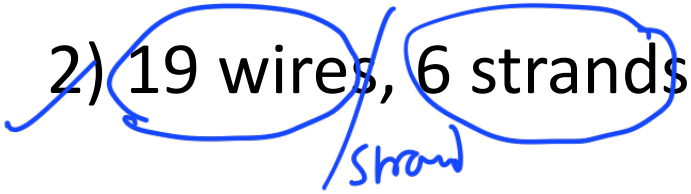
QUIZ

Designation of wire rope

Rope designation 6x19 indicates _____.

1) 6 wires, 19 strands

2) 19 wires, 6 strands



3) None of the above

Rope Design

Rudenko

$$\text{Rope area, } A = \frac{F}{\frac{\sigma_u}{n} - \frac{d}{D_{min}}\frac{d_{wire}}{d}E'} = 0.4 \times \frac{\pi}{4}d^2$$ (d = nom. dia. of rope)

F = load per rope fall

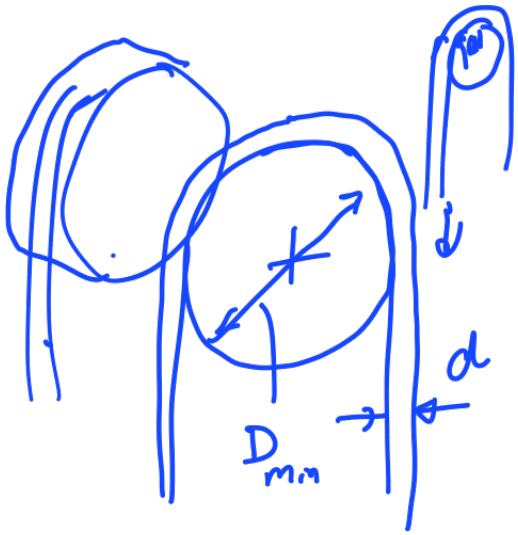
σ_u = UTS of rope wire

n = (*FOS from DDB T27.12*) × *Impact factor*

$\frac{d_{wire}}{d} = \frac{1}{1.5\sqrt{i}}$ where i = number of wires

E' = corrected Young's modulus of wire

= 76,000 MPa for 6x37 rope (Refer Bhandari Textbook)



D_{min}/d as a function of the number of bends in the system :

No. of bends	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
D_{min}/d	16	20	23	25	26.5	28	30	31	32	33	34	35	36	37	37.5	38

EOT Crane Design Specification

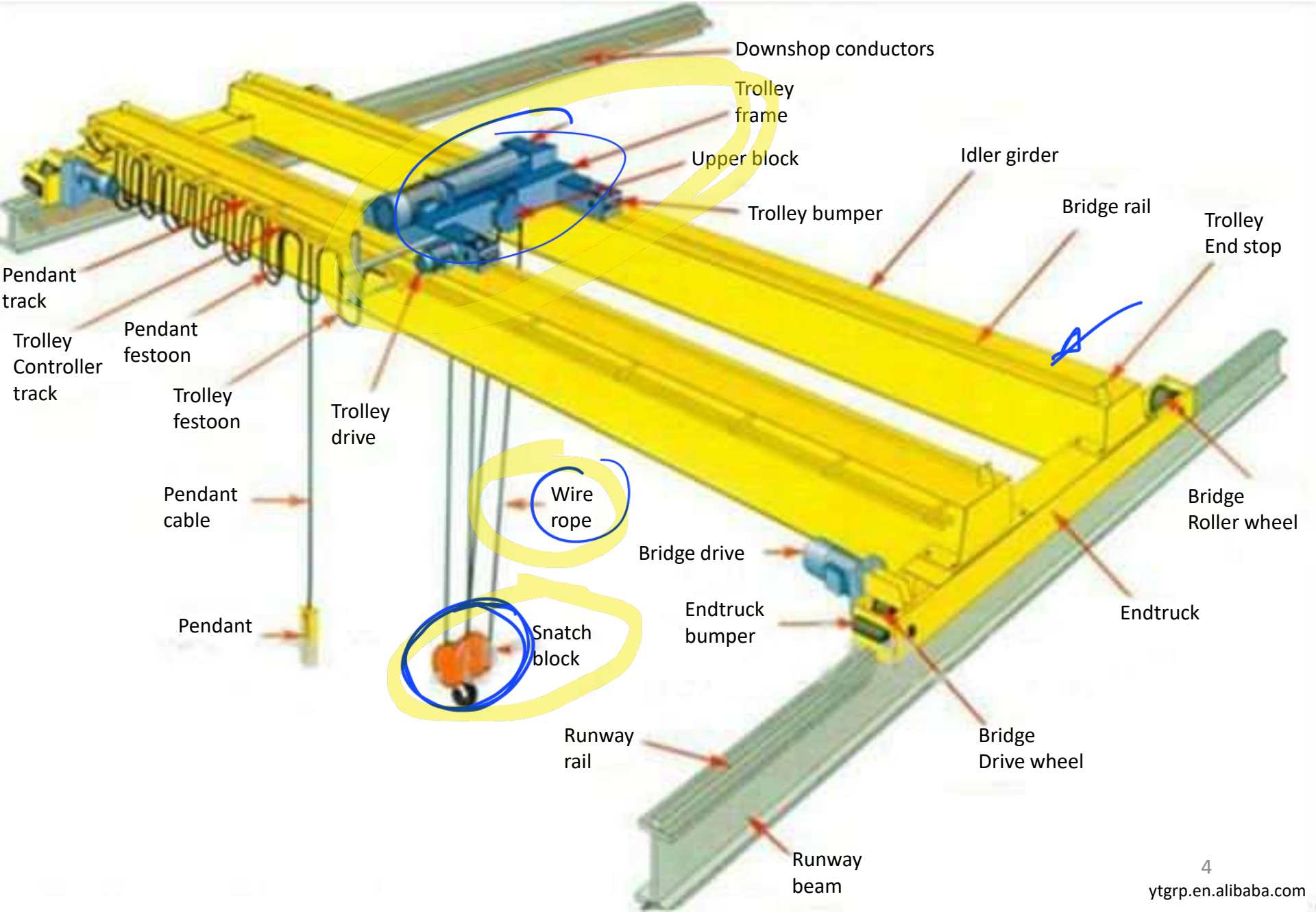
Specification for EOT crane is given as follows

- Safe working load (SWL) = 100 kN
- Lift = 10 m
- Number of rope falls = 4
- Service = heavy duty foundry work
- Number of hours in service = 3500 per year
- Hoisting velocity = 10 m/min
- Braking distance for hoist = 90 mm
- Trolley speed = 25 m/min

Design following parts

- Rope
- Snatch block
- Rope drum
- Trolley

Parts of EOT crane



① Normal Service load calculation (R_N)

Dead weight of components on hoisting mechanism

$R_d = 5$ kN (assumed)

$R_f = 2$ kN (assumed) — experience

Braking dist = 90 mm

velocity = 10 m/min

$v^2 - u^2 = 2as$

$0^2 - \left(\frac{10}{60}\right)^2 = 2 \times a \times 0.090$

$\Rightarrow a = 0.154$ m/s²

R_m = load from deacceleration = $m \times a$

$= \left(\frac{100+5}{9.81}\right) \times 0.154$

$R_m = 1.65$ kN

Class of crane = 3 (DDB T 27.2)

Impact factor = 1.4 (— " —)

$R_{hi} = R_n \times$ Impact Factor $= 100 \times 1.4 = 140\,kN$

$R_n = 100\ kN$

Normal service load

$R_N = \max(5 + 100 + 1.65 + 2,\ 5 + 140) = 145\,kN$

(For structural parts)

For rope

$(R_N)_{rope} = 108.65\ kN$

② Selection of rope

n_f = Number of falls = 4 (given)

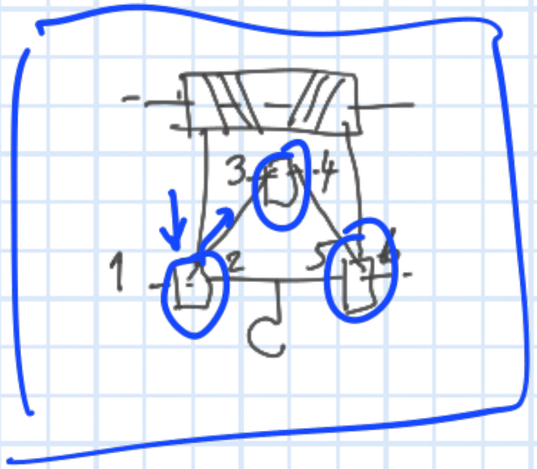
(for 4 fall system)

$$\text{Load per fall} = F = \frac{(R_N)_{rope}}{n_f \cdot \eta} = \frac{108.65}{4 \times 0.94}$$

$$= \boxed{28.9\ kN}$$

$$\text{Number of bends} = N_b = \frac{\text{Number of points where rope runs-on/off}}{2}$$

$$= \frac{6}{2} = 3$$



For establishing factors, we assume 6X37, regular lay rope

QUIZ

Load per fall in wire rope

Load per fall in EOT cranes is _____.

1) Same in stationary and moving conditions

2) Different in stationary and moving conditions

3) None of the above

Area of rope

$$A = \frac{F}{\frac{\sigma_u}{n} - \left(\frac{d}{D_{min}}\right)\left(\frac{d_w}{d}\right) \cdot E'}$$

where

F = load per fall = 28.9 kN

σ_u = 1960 MPa (DDB 27.11)

n = (FOS from DDB T27.12) × I.F.

= 5.0 × 1.4

= 7.0

$\frac{D_{min}}{d} = 23$ ---- Refer table on slide

$\frac{d_w}{d} = \frac{1}{1.5\sqrt{i}}$, i = no. of wires = 6×37 = 222

$= \frac{1}{1.5\sqrt{222}} = 0.0447$

E' = corrected Young's modulus

= 76,000 MPa (Bhandari Textbook Table 23-7)

$$\therefore A = \frac{28.9 \times 10^3}{\left[\frac{1960}{7} - \left(\frac{1}{23}\right)(0.0447) \times 76{,}000\right]}$$

$= 218.5 \text{ mm}^2$

Since $A = 0.4 \times \frac{\pi}{4} d^2$

$\Rightarrow d = 26.3$ mm

Selected rope from DDB T27.11

= 28 mm (6×37, reg'lay, (1960 MPa))

QUIZ

Ratio of pulley and rope diameter

Ratio of pulley to the rope diameter should be _____.

1) Large to reduce bending stresses

2) Large to achieve higher fatigue life

3) Both of the above

QUIZ

Corrected Young's Modulus for Rope

Corrected Young's modulus for wire rope is _____.

1) Smaller than that of the rope wire material

2) Larger than that of the rope wire material

3) Smaller or larger than that of the rope wire material

③ Allowable stresses for structural parts as per IS-3177

Permissible stress, $F_s = \dfrac{UTS}{C_{df} \times C_{bf} \times C_{sf}}$

$UTS = 600$ MPa (for 40C8 steel, DDB T2.24)

C_{df} = Duty factor ~ impact factor = 1.4 (DDB T27.2)

C_{bf} = Basic stress factor

= 3.15 for normal loading

C_{sf} = Safety factor based on material type

= 1.12 for mild steel (IS 3177, T4)

$\therefore F_s = \dfrac{600}{1.4 \times 3.15 \times 1.12} = \boxed{121.5 \text{ MPa}}$

QUIZ

Permissible Stresses for Structural Parts

Factor Cbf (basic load factor) depends on _____.

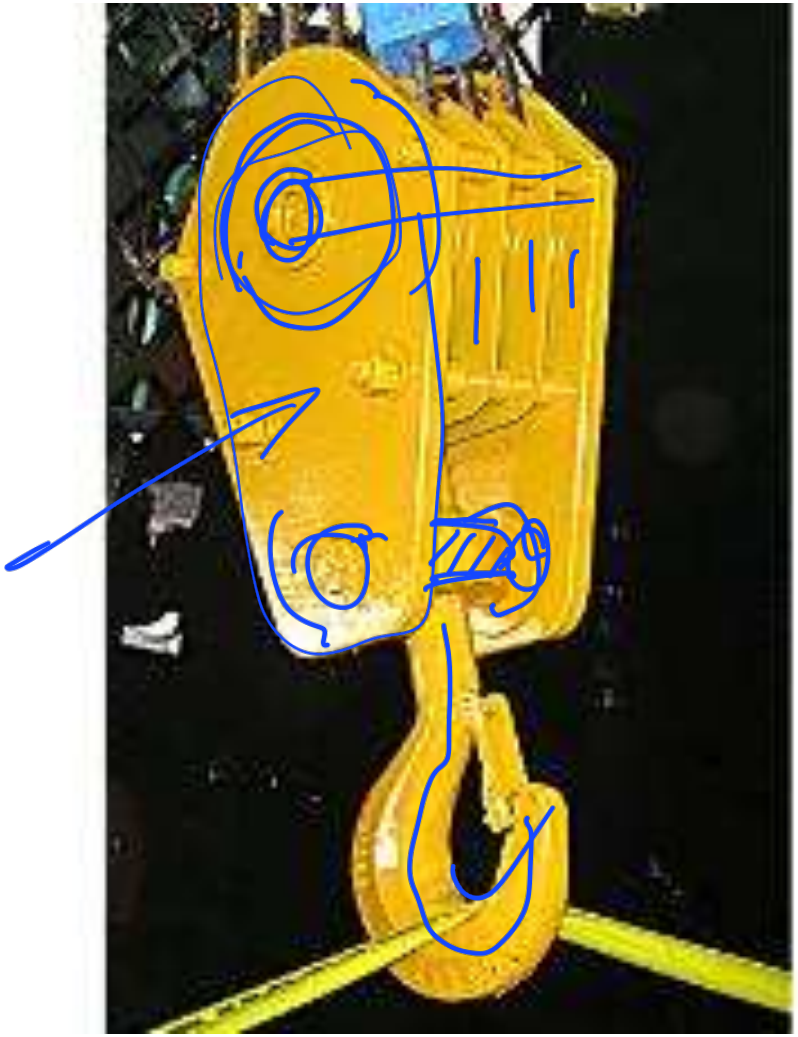
1) Nature of service

2) Type of loading condition

3) None of the above

$$F_s = \frac{UTS}{C_{df} C_{bf} C_{sf}}$$

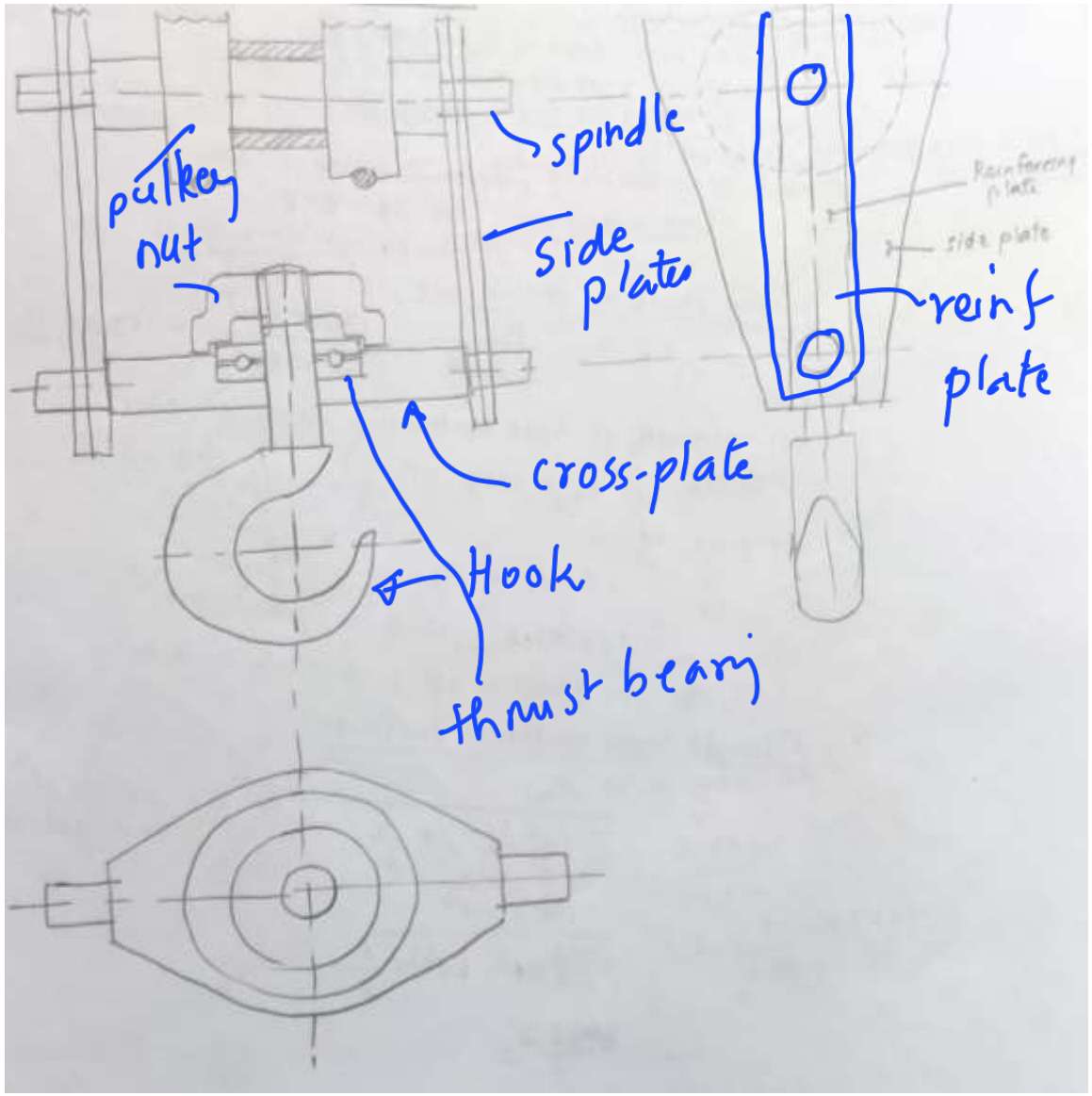
Snatch block



https://suppliers.jimtrade.com/167/166387/snatch_block_assembly_hooks.htm

http://www.eotcranemanufacturers.net/5-ton-snatch-block-780610.html#prod_img

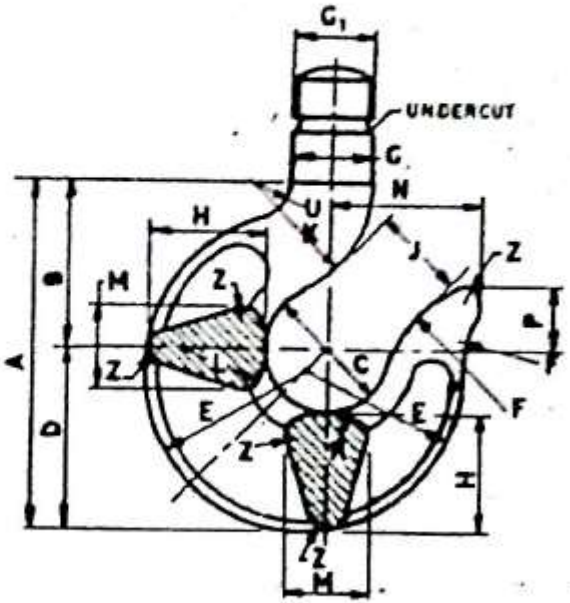
Design of Snatch Block



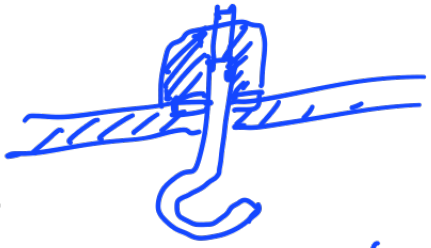
Lifting Hook (IS 3815)

Normal Load for Structural parts = 145 kN = 14.8 tons

Safe load tonnes	Proof Load tonnes	C		G min	THREAD G_1	THREAD pitch	COURSE SERIES Thrust bearings on G Series
0.5	1	27	A = 2.75C	15	M14		
		23	B = 1.31C	12	M12		
			D = 1.44C				
1	2	38	E = 1.25C	20	M20		
		33	F = C	20	M18		511
			H = 0.93C				
2	4	53	J = 0.75C	30	M27		
		46	K = 0.92C	25	M24		512
			L = 0.7 C				
3.2	6.4	68	M = 0.6 C	35	M33		
		59	N = 1.2 C	30	M30		
			P = 0.5 C				
5	10	85	R = 0.5 C	45	M42		
		73	U = 0.3 C	40	M30		
			Z = 0.12C				
8	16	107		55	M52		
		93		50	M48		
10	20	119		60	M60		
		104		55	M52		513
12	25	134		70	M68		
14.8		116		60	M60		
16	32	151		80	M76	6	
		131		70	M68	6	
20	40	169		85	M80	6	
		147		80	M72	6	
25	50	189		100	M90	6	
		164		85	M80	6	



(A) Hook Design



Hook load = 145 kN = 14.8 tons

From IS 3815, we select hook with SWL = 16 tons

Let Thread size = M76 × 6p

Thread calculations

Normal service load = R_N = 145 kN

Let weight of hook & tackle = $0.1 R_N$ = 14.5 kN

∴ Load on hook threads = F_h = 145 + 14.5 = 159.5 kN

Thread core diameter (approx), $d_c \approx$ Major dia. − 2p

= [redacted]

= [redacted] mm