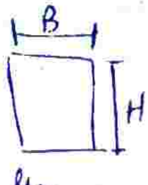
Design

Known Beam dimensions



↓

calculate the required reinforcement

↓

- Force Equili. and Nominal Strength
- Reinforcement ratio and Nominal Strength

$$a = \frac{A_s f_y}{0.85 f'_c B}$$

$$M_u = \phi M_n = \phi A_s f_y \left(d - \frac{a}{2}\right)$$

- بنحل يا إما نعوض a بالمعادلة
- يا إما assumption
  - $a \simeq \frac{d}{3}$
  - بنعوضها بالمعادلة Mu
  - بنحل بـ a check
  - عشان نطلع As
- بنعوض بدل $A_s \to \rho b d$ بالمعادلة الأولى

$$M_u = \phi M_n = \phi \rho f_y B d^2 \left(1 - 0.59 \frac{\rho f_y}{f'_c}\right)$$

Unknown Beam dimensions

Mu ↓

المطلوب ρ, A, B, H

↓

~~Known Bea~~

set the reinforcement ratio

economic reinforcement ← $0.5\rho_{max} \leq \rho \leq 0.75\rho_{max}$

↓

$$\frac{M_u}{\phi b d^2} = \rho f_y \left(1 - 0.59 \frac{\rho f_y}{f'_c}\right)$$

(M_u: هاي بتكون من الـ structural analysis; ϕ: هاي بنفرضها 0.9)

$bd^2 = \square$

↓

Find an adequate section (B, d)

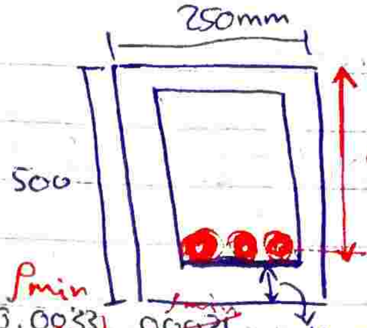
← $d = [1.5 \to 3] B$

بنفرض مثلاً إنه $d = 2B$

ونعوض بهاي ونقربها لأقرب 5cm

Using design Aids on ITC

• **Example:** $M_u = 120$ kN.m
$f'_c = 28$ MPa
$f_y = 420$ MPa



40mm → cover

Assume. $d_b = 16$ mm
. depth channel (Strabs) = 10mm
• $\phi = 0.9$

Design Aids: TABLE A.4

f'_c	B_1	$\rho_{0.005}$	$\rho_{0.004}$	ρ_{min}
28	0.85	0.0181	0.0206	0.00334 ~~0.0031~~

• y_d : بعد سنترويد البار عن الحافة السفلية = $40 + 10 + 8 = 58$ mm
• $d = H - d_y = 500 - 58 = 442$ mm

① iterations:- a → As → Check a
a assume $= \frac{d}{3} = \frac{442}{3} \simeq 140$ mm

[1] • $M_u = \phi A_s f_y (d - a/2) \Rightarrow 120 \times 10^6 = 0.9 A_s 420 (442 - \frac{140}{2})$
$A_s = 853.3$ mm^2

• Check a:- $a = \frac{A_s f_y}{0.85 f'_c B} = \frac{853.3 \times 420}{0.85 \times 28 \times 250} = 60.2$ mm

[2] $a = 80$ mm
. $M_u = \phi A_s f_y (d - a/2) \Rightarrow A_s = 789.7$ mm^2

• check a:- $a = \frac{A_s f_y}{0.85 f'_c B} = 55.7$ mm

بهاد المثال الفرض زبط معنا ، ولكن ع ما يزيد السليوشة أو يبعد ، بنعمل Check → ρ_{max}.

[3] $a = 55$ mm
• $A_s =$ 766 mm^2 → بعتمدها
• Check a ⇒ $a = 54$ mm
لأنها قريبة ع الفرض عشان هيك بنقبلها
« كل 0.03 بنقبل فرقه »

$A_s = 766$ → بنروح ع Design Aids
Table A.2

① 2 ϕ 22
② 4 ϕ 16
③ 6 ϕ 13

← أقرب قيم

بنشوف إذا هاي الخيارات بتوسع بالبيم ←

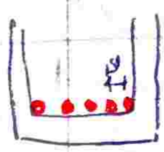
• obtions :-

$\Rightarrow 2\phi 22 \quad \# \; S = 250 - 20 - 44 - 80 = 106 > 25\,mm$ ✓

(S → spaces)

$\Rightarrow 4\phi 16 \quad \# \; 3S \Rightarrow 250 = 80 + 20 + 4 \times 16 + 3S$

$S = 28.6 > 25\,mm$ ✓



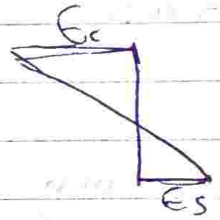
$\Rightarrow 6\phi 13 \quad \# \; 5S \Rightarrow 250 = 80 + 20 + 6 \times 13 + 5S$

$S = 14.4 \not> 25\,mm$ ✗

Design Aids
↳ Table A.7

بدل هاي ممكن أدرج ع

• Check on ϕ :



$0.004 < \rho < 0.005$

Table A.2

$\rho = \frac{A_s}{Bd} = \frac{796}{250 \times 442} = 0.0072 < \rho_{0.005}$ ✓

أقل شي → ρ_{max}

$> \rho_{min}$

• Check on ϕM_n :-

$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{796 \times 420}{0.85 \times 28 \times 442} = 56.18\,mm$

$\phi M_n = \phi A_s f_y \left(d - \frac{a}{2}\right)$

$= 0.9 \times 796 \times 420 \left(442 - \frac{56.18}{2}\right)$

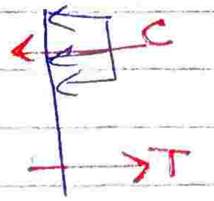
$= 124.5\,kN.m > M_u$ ✓

Note: $A_s \neq n \times \frac{\pi}{4} (d)^2$

• لأنه يكون في فروقات في البارز عشان نرجع قيمة مطابقة للبارات

• القيم اللي تكون بالجداول بتكون مراعية هاد الفرق (الفرق صغير جداً)

* Method 2:-



⇒ $T = C$

- $a = \dfrac{A_s f_y}{0.85 f_c' B}$
- $\phi M_n = \phi A_s f_y (d - \frac{a}{2})$

⇒ $M_u \le \phi M_n = \phi \rho f_y b d^2 \left(1 - 0.59 \rho \frac{f_y}{f_c'}\right)$

R → 120x10⁶

⇒ $\dfrac{M_u}{\phi b d^2}$ = 2.73 MPa → الطلاب اللي صيّا فتوها بعدنا سوّا فطي أخذ بودنص عليها

(d → 442 مثل الطريقة الأولى)

TABLE A.4

β_1	$\rho_{0.005}$ $\epsilon_t = 0.005$	$\rho_{0.004}$ $\epsilon_t = 0.004$	$\rho_{min} = \frac{1.4}{f_y}$	$\rho_{min} = \frac{0.25\sqrt{f_c'}}{f_y}$
0.85	0.0181	0.0206	0.0033	0.0031

→ Table A.5a →

ρ	$f_y = 420$ MPa, $f_c' = 28$
0.0065	2.57
0.007	2.76

نعمل انتربوليشن ما للقيمتين.

- $\dfrac{2.76 - 2.57}{0.007 - 0.0065} = \dfrac{2.73 - 2.57}{x - 0.0065}$ ⇐ (0.007, 2.76), (x, 2.73), ((0.0065), (2.57))

$x = \rho = 0.00692 > \rho_{min}$
$< \rho_{max}$

- $A_s = \rho d b = 764.7\ mm^2$ (ρ → 0.00692, d → 442, b → 250)
- $4\phi 15 \rightarrow A_s = 796\ mm^2$
- $\rho = 0.0072$

بنروح ع الجداول وبنطول البارات اقطرها و ρ → TABLE A.7

TAble A.5a	ρ	f_y 420 MPa, f_c' 28
	0.007	2.76
0.0072	0.0075	2.94

ل ع الانتربوليشن $R = 2.844$ MPa

$R = \dfrac{\phi M_u}{\phi b d^2}$ = 2.844 x0.9x 250 x (442)² = 125 kN.m

$\phi M_n = 125 > M_u$ OK

→ Example: simply supported Beam

↕ span → 4.5 m

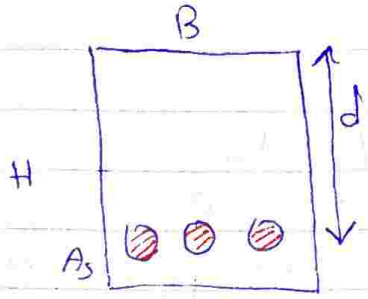
dead load → 20 KN/m

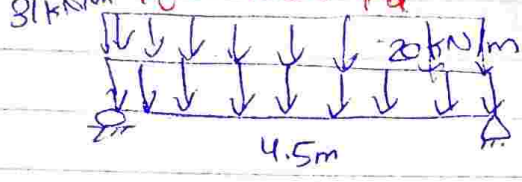
life load → 31 KN/m

$\rho = 0.5\,\rho_{max}$

$f'_c = 28$ MPa

$f_y = 420$ MPa





+ Self weight

1 $M_u = ?$

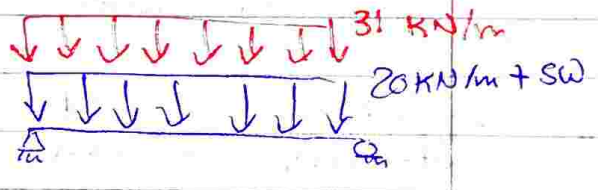
assume

Initial assumptions.

• Table 9.3.1.1 Minimum depth $(H) = \ell/16 = 4.5/16 = 0.3\,m = 300\,mm$

$B = 200\,mm$

• $SW = 1 \times 0.3 \times 0.2 \times \underbrace{\gamma_c}_{24\,KN/m^3} = 1.44 \approx 1.5$



• $W_u = 1.2\,D + 1.6\,L$

$= 1.2(21.5) + 1.6(31)$

$= 75.4\,KN/m$

• Simply supported Beam → $M_u = \frac{wL^2}{8} = \frac{(75.4)(4.5)^2}{8} \approx 191\,KN.m$

• $\rho = 0.5\,\rho_{max} = 0.5 \times \underbrace{0.0206}_{\text{TABLE A.4}} = 0.0103$

TABLE A.5a

• Method 2 : $\rho = 0.0103 \rightarrow R = ??$

ρ	R
0.01	3.83
0.0105	4

$R = 3.93$ MPa

$R = \frac{M_u}{\phi b d^2} \Rightarrow b d^2 = \frac{191\,KN.m}{\phi \times 3.93\,MPa} = 54 \times 10^6\,mm^3$

↳ If $\rho < \rho_{0.005} \rightarrow \phi = 0.9$

• mostly economical → $d = (1.5-3)\,b$

b (mm)	d (mm)
200	520 → factor 2.6 ok
300	425 → 1.5 ok
400	347
250	465

ok $\frac{d}{b}$ تكون < 1.5 ← بصير البيم ضيق ما بوسع للبارات مناسبة.

• d > b

• B → 250 mm

• d ⇒ 465 mm → H = 465 + 40 + 10 + 10 = 525

(d, cover, stirrups, diameter of bar) mm نقربها لأقرب

• Check S.W =

set to ⇒ B = 250 mm

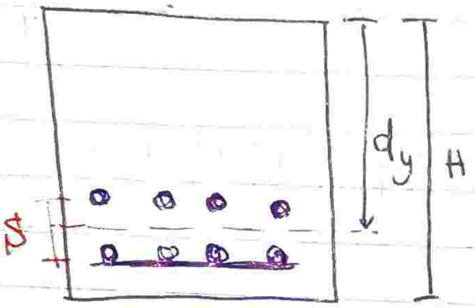
H = 550 mm

S.W = 3.4 KN/m

• $M_u = \frac{(77.7) * (4.5)^2}{8} = 197$ KN.m

→ 1.2(23.4) + 1.6(31)

- positive moment → Bottom reinforcment
- negative moment → Top reinforcment



- لما يكون عنا طبقتين تسليح

$$d_y = H - \left(cover + strabs + d + \frac{1}{2}\delta\right)$$