Arch 324 Structures II

Winter 2026 Recitation 004

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TAUBMAN COLLEGE

Recitation 004

Welcome to session 9!

- Quick Lecture Recap
- Lab: Reinforcement Placement
- **Tower Testing** on **Monday!! :P**

*Homework 9 - deadline moved to <u>next Sunday</u> 4/05

Feel free to ask questions anytime

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Lecture: Concrete Beam Design (3/23 + 3/25)

Rectangular Beam Design

Two approaches:

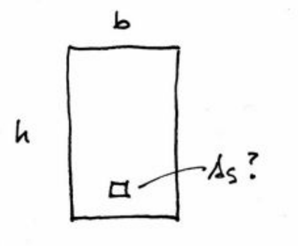
Method 1:

Data:

- Load and Span
- Material properties – f'_c, f_y
- All section dimensions: h and b

Required:

- Steel area – A_s



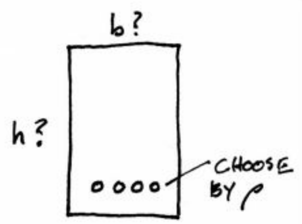
Method 2:

Data:

- Load and Span
- Some section dimensions – h or b
- Material properties – f'_c, f_y
- Choose ρ

Required:

- Steel area – A_s
- Beam dimensions – b or h



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Lecture: Concrete Beam Design (3/23 + 3/25)

Rectangular Beam Design – **Method 1**

Data:
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- All section dimensions – b and h

Required:
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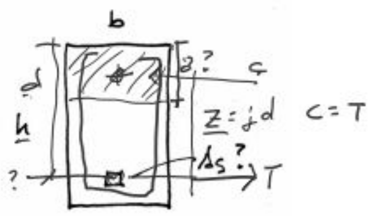

1. Calculate the factored load and find factored required moment, M_u
2. Find d = h – cover – stirrup – $d_b/2$
3. Estimate moment arm z = jd, for beams j ≈ 0.9 for slabs j ≈ 0.95
4. Estimate A_s based on estimate of jd.
5. Use As to find a
6. Use a to find A_s (repeat…until **2%** accuracy)
7. Choose bars for A_s and check A_s max & min
8. Check that $\varepsilon_t \geq 0.005$
9. Check $M_u \leq \phi M_n$ (final condition)

10. Design shear reinforcement (stirrups)
11. Check deflection, crack control, rebar development length

$$M_u = \frac{(\gamma_{DL} w_{DL} + \gamma_{LL} w_{LL}) l^2}{8}$$

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

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

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

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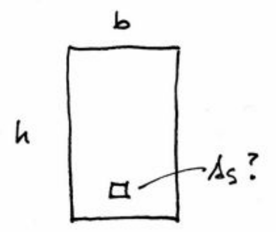

Method 2:

Data:

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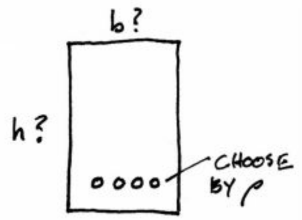
- Choose ρ

Required:

- Steel area – A_s
- Beam dimensions – b or h



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Lecture: Concrete Beam Design (3/23 + 3/25)

Rectangular Beam Design – **Method 2**

Data:

- Load and Span
- Some section dimensions – b or h
- Material properties – f'_c, f_y

Required:

- Steel area - A_s
- Beam dimensions – b and h

1. Estimate the dead load (estimate h and b) ($L/8 \le h \le L/21$, $h = L/12$ and b:h = 1:2 to 2:3), find M_u
2. Choose ρ (equation assumes $\varepsilon_t = 0.0075$)
3. Calculate bd^2
4. Choose b and solve for d (or d and solve b)
5. Revise h, weight, M_u, and bd^2
6. Find $A_s = \rho bd$
7. Choose bars for A_s, determine spacing and cover, and revise d
8. Check that $\varepsilon_t \ge 0.005$ (if not, increase h and reduce A_s)
9. Design shear reinforcement (stirrups)
10. Check deflection, crack control, steel development length

$$M_u = \frac{(\gamma_{DL} w_{DL} + \gamma_{LL} w_{LL}) l^2}{8}$$

$$\rho = \frac{\beta_1 f'_c}{4 f_y}$$

$$bd^2 = \frac{M_u}{\varphi \rho f_y \left(1 - 0.59\rho (fy/f'_c)\right)}$$

$$A_s = \rho b d$$

$$a = \frac{\rho f_y d}{0.85 f'_c}$$

Lecture: Concrete Beam Design (3/23 + 3/25)

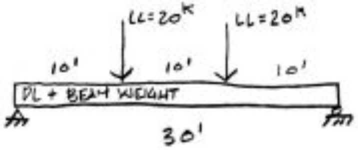
Rectangular Beam Design

Data:
- Load and Span
- Material properties – f'_c, f_y

Required:
- Steel area - A_s
- Beam dimensions – b and d

$f'c$ = 3000 psi
fy = 60 ksi

DL = 2 klf + beam
LL = 2 x 20 k



1. Estimate the dead load (self-weight), and find M_u (h = L/12 and b:h = 1:2 to 2:3)

ASSUME $h \approx \frac{L}{12} = \frac{360''}{12} = 30''$

ASSUME $b:h \approx 1:2 \therefore b \approx 15''$

BEAM DL $= 150 \frac{15 \times 30}{144} = 469$ PLF

ESTIMATE M_U

$$M_U = Pa + \frac{w\ell^2}{8}$$

$$= 1.6(20^k)(10') + \frac{1.2(2.469 \text{ KLF})(30')^2}{8}$$

$$= 320 + 333.3 = 653.3 \text{ K-'}$$

Table 9.3.1.1—Minimum depth of nonprestressed beams

Support condition	Minimum h[1]
Simply supported	ℓ/16
One end continuous	ℓ/18.5
Both ends continuous	ℓ/21
Cantilever	ℓ/8

[1]Expressions applicable for normalweight concrete and f_y = 60,000 psi. For other cases, minimum h shall be modified in accordance with 9.3.1.1.1 through 9.3.1.1.3, as appropriate.

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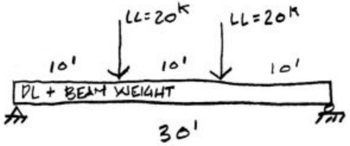

2. Choose ρ (equation assumes $\varepsilon_t = 0.0075$)

f'_c	β_1
0	0.85
1000	0.85
2000	0.85
3000	0.85
4000	0.85
5000	0.8
6000	0.75
7000	0.7
8000	0.65
9000	0.65
10000	0.65

CHOOSE ρ

$$\rho = \frac{\beta_1 f'_c}{4 f_y} = \frac{0.85(3)}{4(60)} = 0.010$$

Lecture: Concrete Beam Design (3/23 + 3/25)

Rectangular Beam Design cont.

3. Calculate bd^2

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

$$bd^2 = \frac{653.3\,(12)}{0.9(0.01)60\left[1 - 0.59(0.01)\left(\frac{60}{3}\right)\right]}$$

$$bd^2 = \frac{7840}{0.573\,(0.882)} = 15492 \text{ in}^3$$

4. Choose b and solve for d
   (or d and solve for b)
   b is based on form size – matches column size
   $h \approx L/12$, $b{:}h \approx 1{:}2$ to $2{:}3$

TRY

b	d	$h \approx 1.12d$	A
14"	33.27"	38"	532
15"	32.14"	36"	540
16"	31.11"	35"	560

CHOOSE 15 x 36

5. Revise h, weight, M_u, and bd^2

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Rectangular Beam Design cont.

5. Revise h, weight, M_u, and bd^2

USE 15 x 36

REVISE $DL = 150 \frac{540}{144} = 563$ PLF

CHECK M_U

$$M_U = 320 + \frac{1.2(2{,}563)30^2}{8} = 666^{K-'}$$

REVISE bd

$$bd^2 = \frac{666(12)}{0.505} = 15814 \text{ in}^3$$

FOR $b = 15''$ $d = 32.5''$

6. Find $A_s = \rho bd$

$$A_s = \rho bd = (0.01)(15'')(32.5'')$$

$$A_s = 4.87 \text{ in}^2$$

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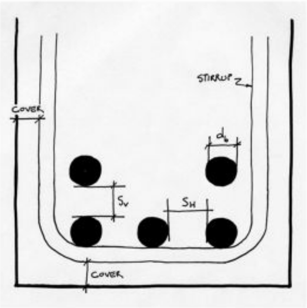
Rectangular Beam Design

7. Choose bars for A_s, determine spacing and cover, and revise d



If bars do not fit in one layer, d is measured to the centroid of the pattern.

$$\bar{x} = \frac{\sum \mathbf{A} \times d_x}{\sum \mathbf{A}}$$

CHOOSE BARS (SEE TABLE A.4)

TRY 5 x #9 BARS $A_s = 5.0 \text{ in}^2$ > **4.87 in²**

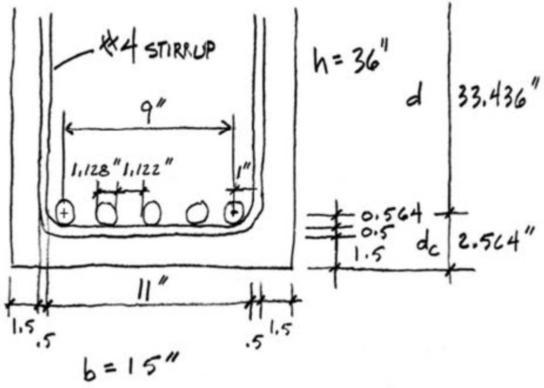


Table A.4 Areas of Groups of StandardBars (in.²)

Bar No.	Number of Bars 2	3	4	5	6	7	8	9	10	11	12	13	14
4	0.39	0.58	0.78	0.98	1.18	1.37	1.57	1.77	1.96	2.16	2.36	2.55	2.75
5	0.61	0.91	1.23	1.53	1.84	2.15	2.45	2.76	3.07	3.37	3.68	3.99	4.30
6	0.88	1.32	1.77	2.21	2.65	3.09	3.53	3.98	4.42	4.86	5.30	5.74	6.19
7	1.20	1.80	2.41	3.01	3.61	4.21	4.81	5.41	6.01	6.61	7.22	7.82	8.42
8	1.57	2.35	3.14	3.93	4.71	5.50	6.28	7.07	7.85	8.64	9.43	10.21	11.00
9	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00
10	2.53	3.79	5.06	6.33	7.59	8.86	10.12	11.39	12.66	13.92	15.19	16.45	17.72
11	3.12	4.68	6.25	7.81	9.37	10.94	12.50	14.06	15.62	17.19	18.75	20.31	21.87
14	4.50	6.75	9.00	11.25	13.50	15.75	18.00	20.25	22.50	24.75	27.00	29.25	31.50
18	8.00	12.00	16.00	20.00	24.00	28.00	32.00	36.00	40.00	44.00	48.00	52.00	56.00

Jack C McCormac, 1978
Design of Reinforced Concrete,

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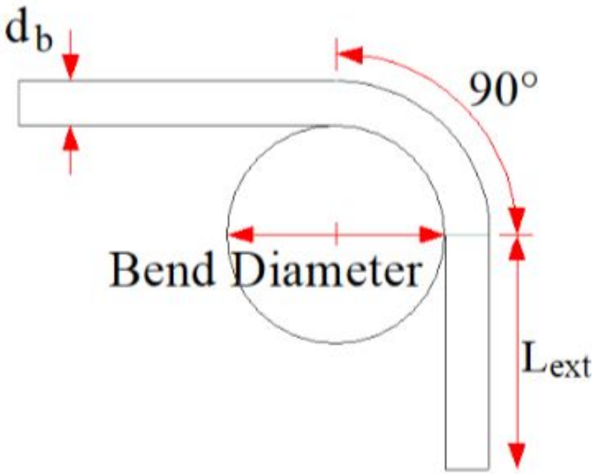
Lab: Reinforcement Placement



Bar size	#3 #4 #5	#6 #7 #8
Min. Bend Diameter	$4d_b$	$6d_b$
Min. L_{ext}	$6d_b$, 3"	$12d_b$

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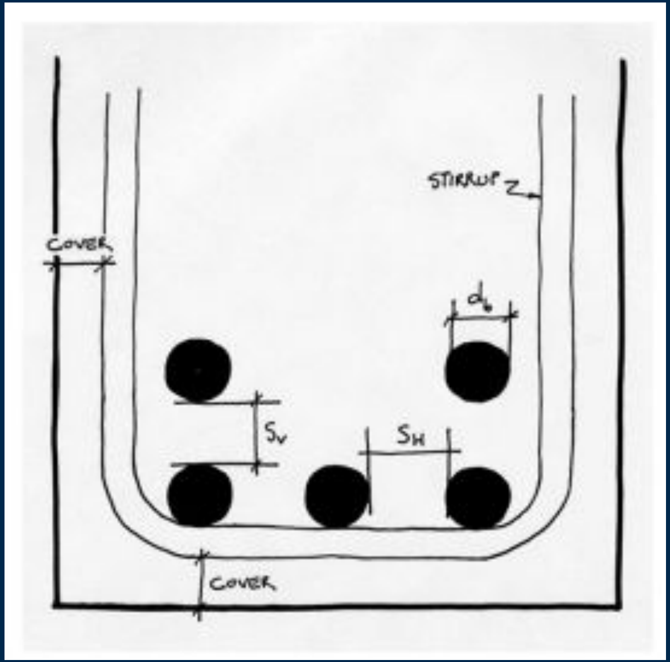
Lab: Reinforcement Placement



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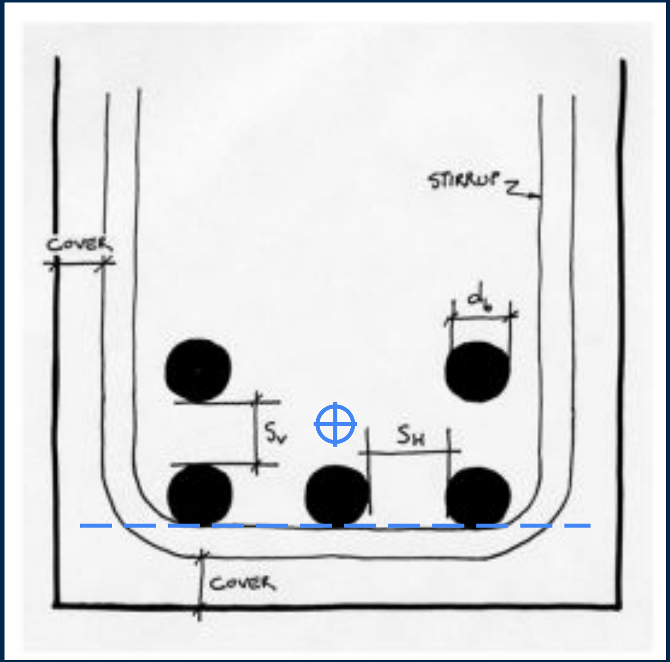
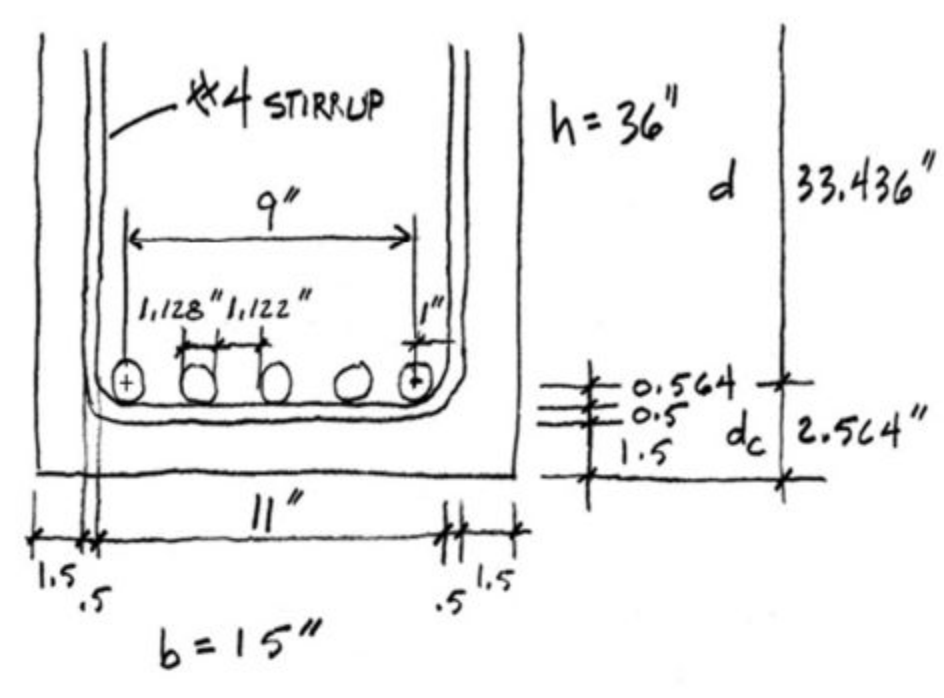
Lab: Reinforcement Placement



$$a = \frac{A_s f_y}{.85 f'_c b} = \frac{5(60)}{.85(3)15} = 7.843''$$

Lab: Reinforcement Placement



Tower Testing Monday!!

Any Questions?

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