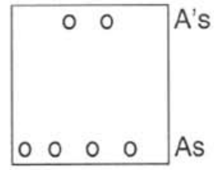
d =	22.2	in	Comp
d' =	2.5	in	
b =	12	in	
f'c =	5000	psi	
fy =	60000	psi	
W_L =	1.205	k/ft	Tension
W_D =	1.21	k/ft	
1 or 2	1		1 = Simply supported, 2=cantilevered beam
L =	40	ft	Span
Mu =	8112	in.kips	
β_1 =	0.8		



Choose c/d ratio

c/d = 0.300

ϕ = 0.90

$$\rho = 0.85\beta_1 \frac{c}{d}\frac{f_c'}{f_y}$$

ρ = 0.0170

As - A's= 4.53 in^2

$$A_{s1} = A_s - A_s' = \rho bd$$

a = 5.328

$$a = \frac{(A_s - A_s')f_y}{0.85 f_c' b}$$

Mn = 5308 in.kips

M_{u2}= 4778 in.kips

$$M_{u2} = \phi(A_s - A_s')f_y(d - a/2)$$

M_{u1} = M_u -M_{u2}= 3334 in.kips

Find the compression steel. First check to see if the compression steel will yield at failure

$$M_{u1} = \phi(A_s')f_y(d - d')$$

A's = 3.13 in^2

$$A_s' = \frac{M_{u1}}{\phi f_y(d - d')}$$

Find Find Tension Steel

As = 7.66 in^2

$$A_s = (A_s - A_s') + A_s'$$

Tension Steel

No.	Bar size		
4	9	4.00	in^2
4	9	4.00	in^2
	------>	8.00	in^2

Compression Steel

No.	Bar size		
4	8	3.16	in^2

Check final design to see if the compression steel will yield with chosen desigr

Check to see if the compression steel yields at balanced condition

$$\frac{A_s - A_s'}{bd} \geq ? \; 0.85\beta_1 \frac{f_c'}{f_y} \frac{87}{87 - f_y} \frac{d'}{d}$$

if yes, the compression steel will yeild at ultimate strengtr

(As-A's)/bd	>= ?	0.85*beta_1* (f'c/fy) * (d'/d)*(87000/(87000-fy))
0.0182	No	0.0206
	Compression Steel does not yield	

A_s^{min} =

$$A_{min} = \frac{3\sqrt{f_c'}}{f_y} bd \geq \frac{200}{f_y} bd$$

A_s^{min} =	0.94 >=	0.888
A_s^{min} =	0.94	in^2

A_s^{min} <	As =	8.00
---->	Therefore it does satisfy the ACI code requirements	

Chosen steel properties

No. of bars =	4	Stirrup db =	0.5
bar size=	9	Stirrup #	4
bar diameter =	1.128 inches		
bar area =	1 in^2	clear spacing=	1.16 inches
width (b) =	12 in		
chosen cover	1.5	bar spacing is	ok

Final moment capacity with the chosen dimensions and reinforcing stee

IF COMPRESSION STEEL YEILDS=

a = 5.69 in

c = 7.12 in

$$a = \frac{(A_s - A_s')f_y}{0.85 f_c' b}$$

c/d = 0.321

Tension-Controlled - Satisfies ACI Code

$$M_{u1} = \phi(A_s')f_y(d - d')$$

M_{u1}= 3362 in.kips

$$M_{u2} = \phi(A_s - A_s')f_y(d - a/2)$$

M_{u2}= 5058 in.kips

$M_u = M_{u1} + M_{u2}$

M_u= 8420 in.kips

> 8112 in.kip

OK

IF COMPRESSION STEEL DOES NOT YEILD=

$$C_s = A_s' f_s' = A_s' \varepsilon_s' E_s = A_s' \left(0.003 \frac{c - d'}{c}\right) E_s$$

$$C_c = 0.85 f_c' \beta_1 c b$$

$$T_s = A_s f_y$$

c = 7.33 in Equilibrium = 0 kips

	Force	Arm	Moment
Cs =	181	19.70	3569
Cc =	299	19.27	5762
Ts=	480	0.00	0

Mn = 9331 in-kips

Mu = 8398 in-kips

> 8112 in.kip

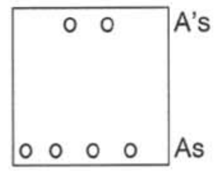
OK

Mn = 778 ft-kips

Mu = 700 ft-kips

Comp

d =	22.2	in
d' =	2.5	in
b =	12	in
f'c =	5000	psi
fy =	60000	psi
W_L =	1.205	k/ft
W_D =	1.21	k/ft
1 or 2	1	
L =	40	ft
Mu =	8112	in.kips
β_1 =	0.8	



Tension

1 = Simply supported, 2=cantilevered bear

Span

Choose c/d ratio

c/d = 0.375

ϕ = 0.90

$$\rho = 0.85\beta_1 \frac{c}{d}\frac{f_c'}{f_y}$$

ρ = 0.0213

As - A's= 5.66 in^2

$$A_{s1} = A_s - A_s' = \rho bd$$

a = 6.66

$$a = \frac{(A_s - A_s')f_y}{0.85 f_c' b}$$

Mn = 6409 in.kips

M_{u2}= 5747 in.kips

$$M_{u2} = \phi(A_s - A_s')f_y(d - a/2)$$

M_{u1} = M_u -M_{u2}= 2365 in.kips

Find the compression steel. First check to see if the compression steel will yield at failure

$$M_{u1} = \phi(A_s')f_y(d - d')$$

$$A_s' = \frac{M_{u1}}{\phi f_y(d - d')}$$

A's = 2.23 in^2

Find Find Tension Steel

As = 7.89 in^2

$$A_s = (A_s - A_s') + A_s'$$

Tension Steel

No.	Bar size		
4	9	4.00	in^2
4	9	4.00	in^2
	------>	8.00	in^2

Compression Steel

No.	Bar size		
3	8	2.37	in^2

Check final design to see if the compression steel will yield with chosen desigr

Check to see if the compression steel yields at balanced condition

$$\frac{A_s - A_s'}{bd} \geq ?\ 0.85\beta_1 \frac{f_c'}{f_y}\frac{87}{87-f_y}\frac{d'}{d}$$

if yes, the compression steel will yeild at ultimate strengtr

(As-A's)/bd	>= ?	0.85*beta_1* (f'c/fy) * (d'/d)*(87000/(87000-fy))
0.0211	Yes	0.0206
	Compression Steel Yields	

A_s^{min} =

$$A_{min} = \frac{3\sqrt{f_c'}}{f_y}bd \geq \frac{200}{f_y}bd$$

A_s^{min} =	0.94 >=	0.888	
A_s^{min} =	0.94	in^2	
A_s^{min} <		As =	8.00
---->		Therefore it does satisfy the ACI code requirements	

Chosen steel properties

No. of bars =	4	Stirrup db =	0.5
bar size=	9	Stirrup #	4
bar diameter :	1.128 inches		
bar area =	1 in^2	clear spacing=	1.16 inches
width (b) =	12 in		
chosen cover	1.5	bar spacing is	ok

Final moment capacity with the chosen dimensions and reinforcing stee

IF COMPRESSION STEEL YEILDS=

$$a = \frac{(A_s - A_s')f_y}{0.85 f_c' b}$$

a = 6.62 in

c = 8.28 in

c/d = 0.373

Tension-Controlled - Satisfies ACI Code

$$M_{u1} = \phi(A_s')f_y(d - d')$$

M_{u1}= 2512 in.kips

$$M_{u2} = \phi(A_s - A_s')f_y(d - a/2)$$

M_{u2}= 5721 in.kips

M_u= M_{u1} + M_{u2}

M_u= 8233 in.kips

\> 8112 in.kip

OK

IF COMPRESSION STEEL DOES NOT YEILD=

$$C_s = A_s'f_s' = A_s'\varepsilon_s'E_s = A_s'\left(0.003\frac{c-d'}{c}\right)E_s$$

$$C_c = 0.85 f_c'\beta_1 cb$$

$$T_s = A_s f_y$$

c = 7.33 in Equilibrium = -45 kips

	Force	Arm	Moment
Cs =	136	19.70	2677
Cc =	299	19.27	5762
Ts=	480	0.00	0

Mn = 8439 in-kips

Mu = 7567 in-kips

\> 8112 in.kip

ıgth Requiremeı

Mn = 703 ft-kips

Mu = 631 ft-kips

6.9. Example: Design of a member to satisfy a nominal moment capacity.

A doubly reinforced concrete beam section has a maximum effective depth d = 25 in and is subjected to a total factored moment M_u = 9400 in-kips, including self weight. Design the section and select the appropriate reinforcement at the tension and the compression faces to carry the required load.

$$f_y = 60,000 \ psi$$

$$f_c' = 4,000 \ psi$$

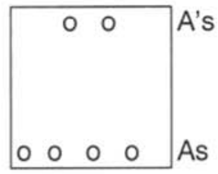
$$Required \quad M_n = 9,400 \ in\text{–}k$$

Solution

Assume that b = 14 in. = 0.55 d

See the following pages for design done in a spreadsheet.

d =	25	in	Comp
d' =	2.5	in	
b =	14	in	
f'c =	4000	psi	
fy =	60000	psi	
W_L =	1.4	k/ft	Tension
W_D =	1.4	k/ft	
1 or 2	1		1 = Simply supported, 2=cantilevered bearr
L =	40	ft	Span
Mu =	9408	in.kips	
β_1 =	0.85		



Choose c/d ratio

c/d = 0.333

ϕ = 0.90

$$\rho = 0.85\beta_1 \frac{c}{d}\frac{f_c'}{f_y}$$

ρ = 0.0160

As - A's= 5.61 in^2

$$A_{s1} = A_s - A_s' = \rho bd$$

a = 7.07625

$$a = \frac{(A_s - A_s')f_y}{0.85 f_c' b}$$

Mn = 7229 in.kips

M_{u2}= 6506 in.kips

$$M_{u2} = \phi(A_s - A_s')f_y(d - a/2)$$

M_{u1} = M_u -M_{u2}= 2902 in.kips

Find the compression steel. First check to see if the compression steel will yield at failure

$$M_{u1} = \phi(A_s')f_y(d - d')$$

$$A_s' = \frac{M_{u1}}{\phi f_y(d - d')}$$

A's = 2.39 in^2

Find Find Tension Steel

As = 8.00 in^2

$$A_s = (A_s - A_s') + A_s'$$

Tension Steel

No.	Bar size		
4	9	4.00	in^2
4	9	4.00	in^2
	------>	8.00	in^2

Compression Steel

No.	Bar size		
4	7	2.40	in^2

Check final design to see if the compression steel will yield with chosen desigr

Check to see if the compression steel yields at balanced condition

$$\frac{A_s - A_s'}{bd} \geq ?\ 0.85\beta_1 \frac{f_c'}{f_y} \frac{87}{87 - f_y} \frac{d'}{d}$$

if yes, the compression steel will yeild at ultimate strengtł

(As-A's)/bd	>= ?	0.85*beta_1* (f'c/fy) * (d'/d)*(87000/(87000-fy))
0.0160	Yes	0.0155
	Compression Steel Yields	

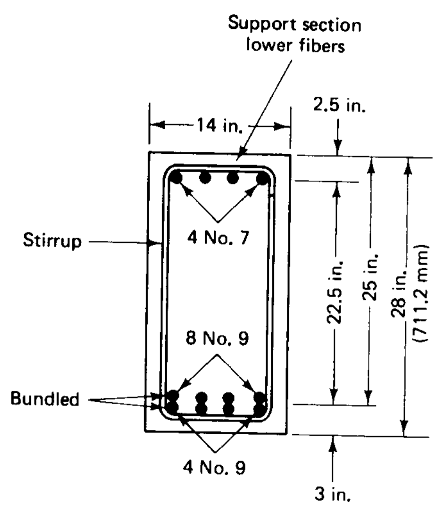
A_s^{min} =

$$A_{min} = \frac{3\sqrt{f_c'}}{f_y} bd \geq \frac{200}{f_y} bd$$

A_s^{min} =	1.11 >=	1.166666667	
A_s^{min} =	1.17	in^2	
A_s^{min} <		As =	8.00
---->		Therefore it does satisfy the ACI code requirements	

Chosen steel properties

No. of bars =	4		Stirrup db =	0.5	
bar size=	9		Stirrup #	4	
bar diameter =	1.128	inches			
bar area =	1	in^2	clear spacing=	1.83	inches
width (b) =	14	in			
chosen cover	1.5		bar spacing is	ok	



Final moment capacity with the chosen dimensions and reinforcing stee

IF COMPRESSION STEEL YEILDS=

$$a = \frac{(A_s - A_s')f_y}{0.85 f_c' b}$$

a = 7.06 in

c = 8.30 in

c/d = 0.332

Tension-Controlled - Satisfies ACI Code

$$M_{u1} = \phi(A_s')f_y(d - d')$$

M_{u1}= 2916 in.kips

$$M_{u2} = \phi(A_s - A_s')f_y(d - a/2)$$

M_{u2}= 6493 in.kips

M_u= M_{u1} + M_{u2}

M_u= 9409 in.kips

> 9408 in.kip

OK

IF COMPRESSION STEEL DOES NOT YEILD=

$$C_s = A_s' f_s' = A_s' \varepsilon_s' E_s = A_s' \left(0.003 \frac{c - d'}{c}\right) E_s$$

$$C_c = 0.85 f_c' \beta_1 c b$$

$$T_s = A_s f_y$$

c = 7.33 in Equilibrium = -46 kips

	Force	Arm	Moment
Cs =	138	22.50	3096
Cc =	297	21.88	6490
Ts=	480	0.00	0

Mn = 9586 in-kips

Mu = 8627 in-kips

> 9408 in.kip

ngth Requiremen

Mn = 799 ft-kips

Mu = 719 ft-kips