BIRZEIT UNIVERSITY

Reinforced Concrete Design 1

ENCE335

Project : Phase 2

Dr. Khalil Qatu

Section 1

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Calculate the dead load :

H_{min} = 300 mm .

Super imposed dead loads :

- Plastering = 0.02*1*1*22= 0.44 KN/m2

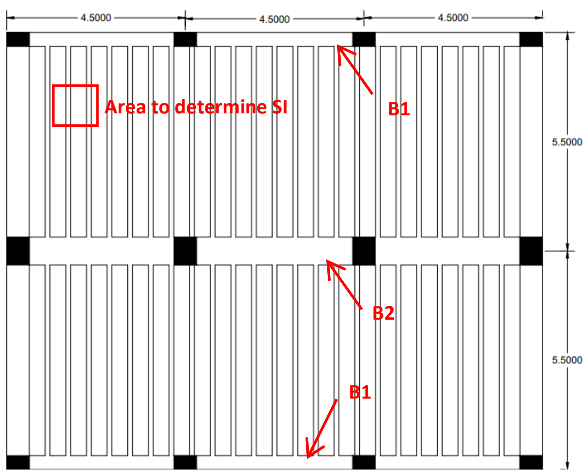
- Fill = 0.1*1*1*18= 1.8 KN/m2

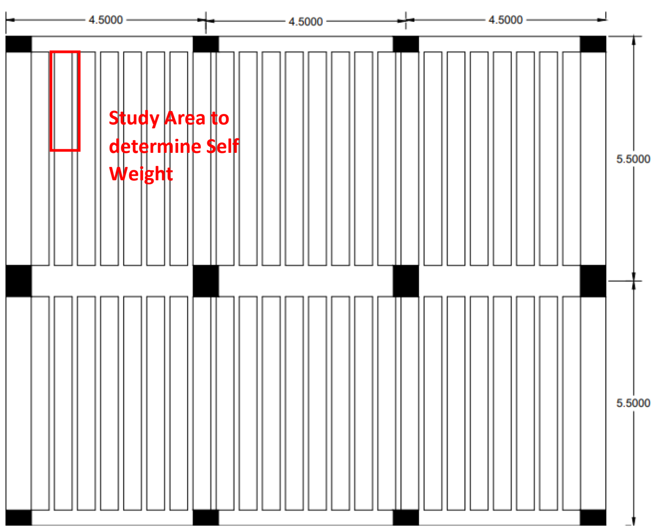
- Mortar = 0.03*1*1*22 = 0.66 KN/m2

- Tiles = 20 kg/m2 = 0.2 kN/m2

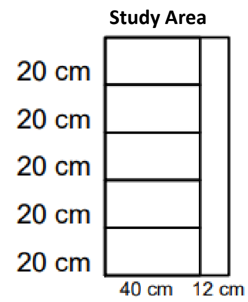
Total SI= 3.1 kN/m2

Partitions = 1.5 kN/m2





Self Weight :



H = 300 mm = 30 cm

Hs = max { 40mm (with filler) , 400/12=33.3 mm}

= 40 mm

HB ~(24 cm) , (20 Kg)

HB= 5*20/100 = 1 KN

Top Slab (6 cm) > hs=4cm

Top Slab = (0.06)*(0.4)*(1)*(24) = 0.576 KN

Rib = (0.3)*(0.12)*(1)*(24) = 0.864 KN

Total dead load for study area = 2.44 KN

Total dead load / m2 = 2.44/0.52 = **4.7 KN/m2**

Total Dead Load = S.W + SI + Partitions = 9.3 KN/m2

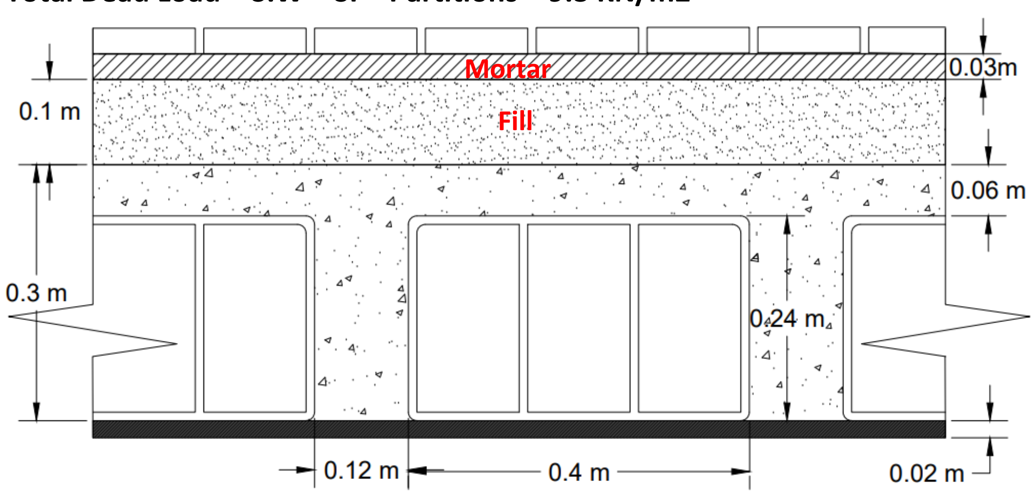


TABLE 1.1
(Continued)

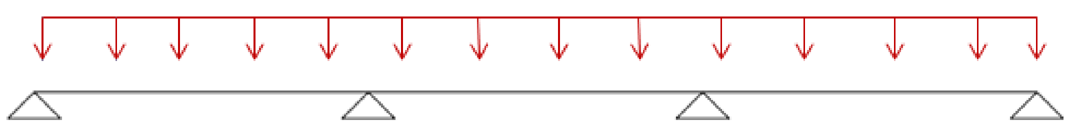
Occupancy or Use	Live Load, kN/m²	Occupancy or Use	Live Load, kN/m²
Offices	2.4	Schools	
Corridors above first floor	3.8	Classrooms	1.9
Penal institutions		Corridors above first floor	3.8
Cell blocks	1.9	First-floor corridors	4.8
Corridors	4.8	Sidewalks, vehicular driveways, and yards	12.0
Residential		subject to trucking[d]	
Dwellings (one and two-family)		Stadiums and arenas	
Uninhabitable attics without storage	0.5	Bleachers[b]	4.8
Uninhabitable attics with storage	1.0	Fixed seats (fastened to floor)[b]	2.9
Habitable attics and sleeping areas	1.4	Stairs and exit ways	4.8
All other areas except stairs and balconies	1.9	One and two-family residences only	1.9
Hotels and multifamily houses		Storage areas above ceilings	1.0
Private rooms and corridors serving them	1.9	Storage warehouses (shall be designed for	
Public rooms and corridors serving them	4.8	heavier loads if required for anticipated storage)	

Live Load = 1.9 KN/m2

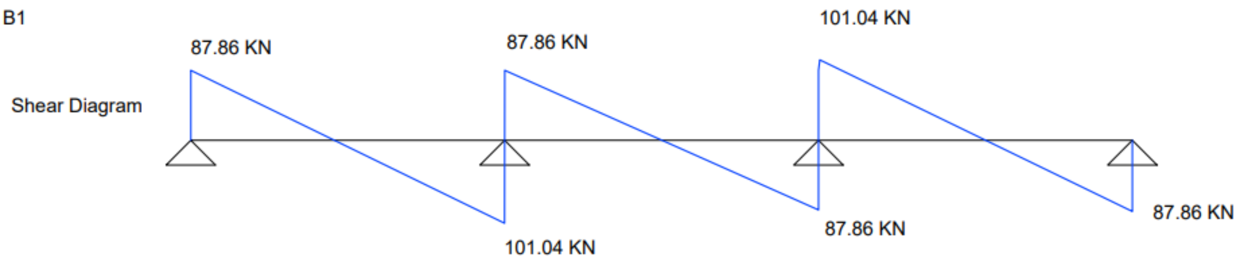
Ultimate Uniformly Load = 1.2*(DL)+1.6*(LL) = 14.2 KN/m2

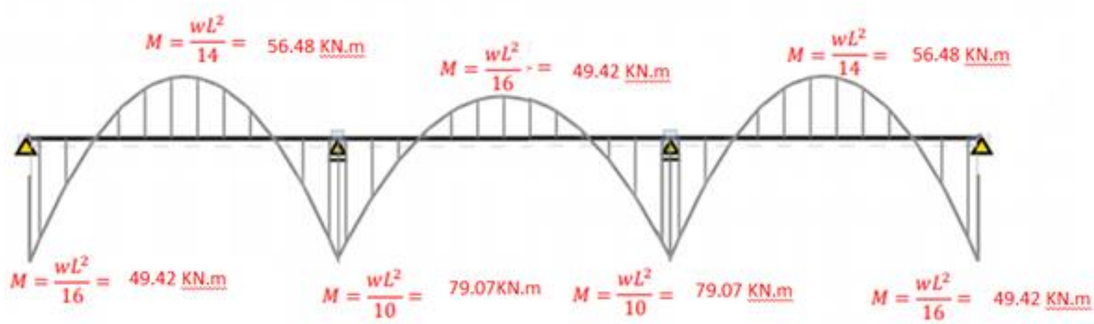
Using ACI coefficients (applied ACI code requirements) :

B1 : (W = W_u *(2.75) = 39.05 KN/m)

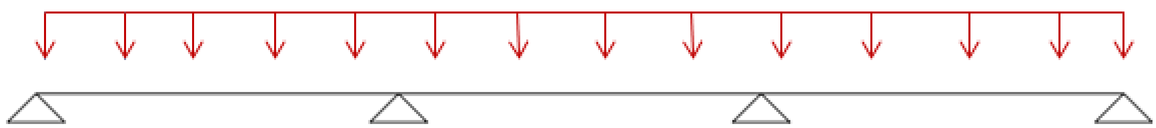


B1

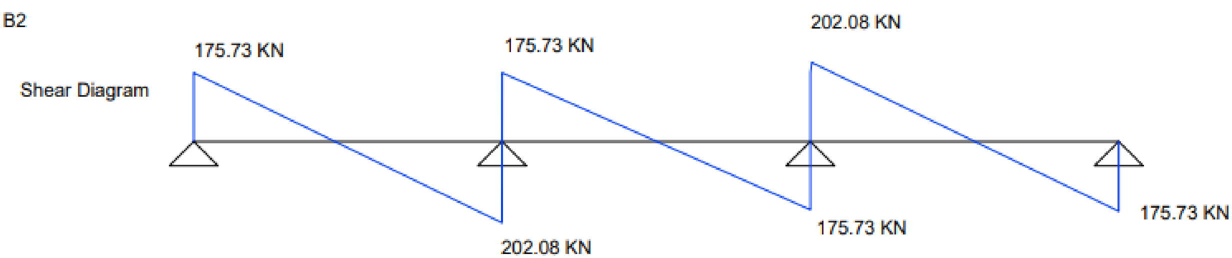


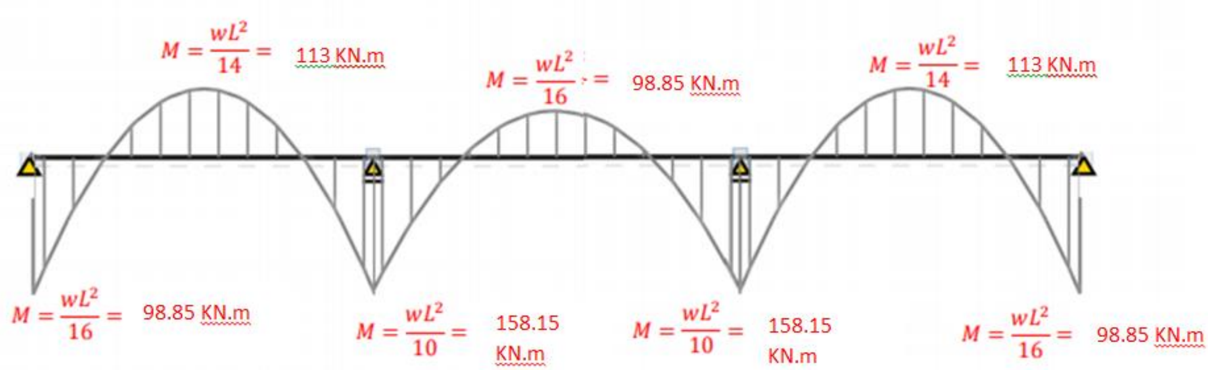


B2 : (W = W_u *(5.5) = 78.1 KN/m)



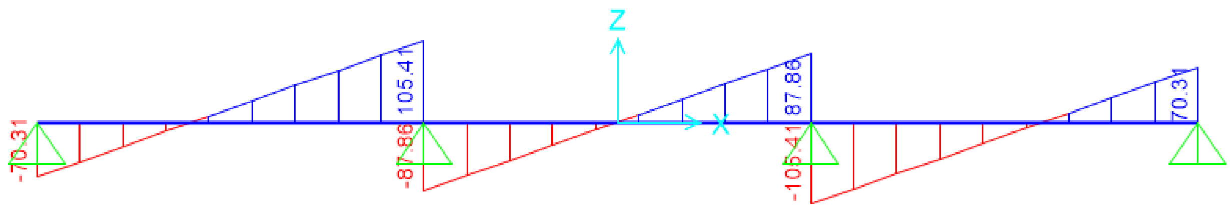
B2

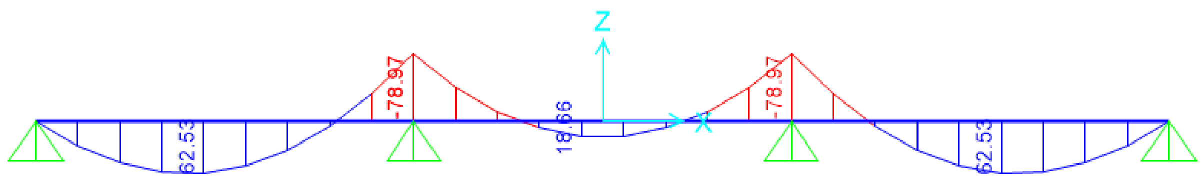




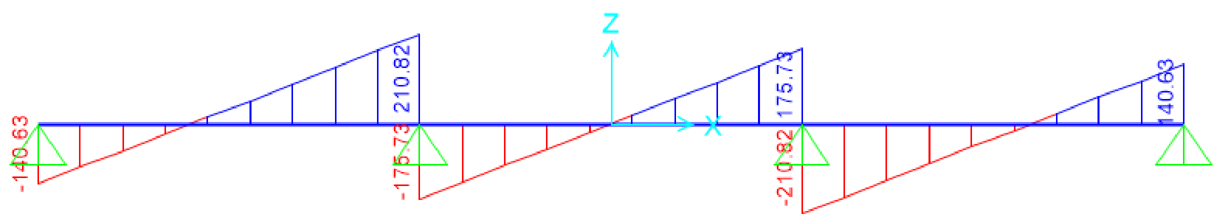
Analyze the beams using SAP2000 :

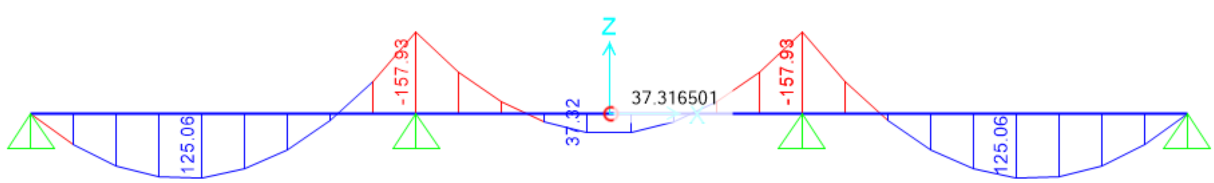
B1 :





B2:





Design of Beams :

yield strength of steel used **fy** = 420 MPa

Compressive strength of concrete **fc'** = 28 MPa

From table A.4:

ρ 0.005	ρ0.004(max)	ρ(min)	β1
0.0181	0.0206	0.0033	0.85

Moment Design of beams:

Assume:

*One layer.

*Cover=40mm.

*dst. = 10mm.

*dbar=16mm.

*dagg=19mm.

*d=300-40-10-16/2=242mm.

<u>Note: positive moment has a bottom reinforcement, and negative moment has a top reinforcement.</u>

<u>B1:</u>

We have three different values of moment; each one has a different reinforcement:

1.Mu=79.07 KN.m.

*Assume ρ=0.6ρmax =0.01236

(4.67-4.51)/(0.0125-0.012) =(R-4.51)/(0.01236-0.012)

R=4.625MPa

R=Mu/(Φbd^2)>>b==300mm.

We use 300mm to the three cases.

ρ	R
0.012	4.51
0.0125	4.67

Assume Φ=0.9

*R= Mu/(Φbd^2) =5 MPa.

*From table A.5a:

(0.014-0.0135)/ (5.15-4.99) = (ρ-0.0135)/ (5-4.99)

ρmax>ρ=0.01353>ρmin, OK.

*As=ρ b d=982.3mm^2.

From table A.2:

5Φ16>> As=995mm^2.

Check spacing: from table A.7, OK.

ρ	R
0.0135	4.99
0.014	5.15

*As=ρ b d>> ρ = 0.0137

ρ0.005>ρ>ρmin, OK>>Φ=0.9.

*From table A.5a:

(5.15-4.99)/ (0.014-0.0135) = (R-4.99)/ (0.0137-0.0135)

R=5.054 MPa.

Check Mn:

ρ	R
0.0135	4.99
0.014	5.15

Mn=RΦbd^2=79.915 KN.m.

Mn > Mu, OK.

<u>2.Mu=56.48 KN.m.</u>

Assume Φ=0.9

*R= Mu/(Φbd^2) =3.57 MPa.

*From table A.5a:

ρ	R
0.009	3.48
0.0095	3.57

(0.0095-0.009)/ (3.66-3.48) = (ρ-0.009)/ (3.57-3.48)

ρmax>ρ=0.00925>ρmin, OK.

*As=ρ b d=671.55mm^2.

From table A.2:

4Φ16>> As=796mm^2.

Check spacing: from table A.7, OK.

*As=ρ b d>> ρ = 0.0109

ρ0.005>ρ>ρmin, OK>>Φ=0.9.

*From table A.5a:

ρ	R
0.0105	4.00
0.0110	4.17

(4.17-4)/ (0.011-0.0105) = (R-4)/ (0.0109-0.0105)

R=4.136MPa.

Check Mn:

Mn=RΦbd^2=65.399 KN.m.

Mn > Mu, OK.

3.Mu=49.42KN.m.

Assume Φ=0.9

*R= Mu/(Φbd^2) =3.125MPa.

*From table A.5a:

ρ	R
0.008	3.12
0.0085	3.30

(0.0085-0.008)/ (3.3-3.12) = (ρ-0.008)/ (3.125-3.12)

ρmax>ρ=0.00801>ρmin, OK.

*As=ρ b d=581.8mm^2.

From table A.2:

3Φ16>> As=597mm^2.

Check spacing: from table A.7, OK.

*As=ρ b d>> ρ = 0.00822

ρmax>ρ>ρmin, OK>>Φ=0.9.

*From table A.5a:

ρ	R
0.008	3.12
0.0085	3.30

(3.3-3.12)/ (0.0085-0.008) = (R-3.12)/ (0.00822-0.008)

R=3.1992MPa.

Check Mn:

Mn=RΦbd^2=50.58 KN.m.

Mn > Mu, OK.

B2:

We have three different values of moment; each one has a different reinforcement:

1.Mu=158.14KN.m.

*Assume ρ=0.6ρmax =0.01236

(4.67-4.51)/(0.0125-0.012) =(R-4.51)/(0.01236-0.012)

R=4.625MPa

R=Mu/(Φbd^2)>>b=754.55mm==700mm.

We use 700mm to the three cases.

ρ	R
0.012	4.51
0.0125	4.67

Assume Φ=0.9

*R= Mu/(Φbd^2) =4.286 MPa.

*From table A.5a:

(0.0115-0.011)/ (4.34-4.17) = (ρ-0.011)/ (4.286-4.17)

ρmax>ρ=0.0113>ρmin, OK.

*As=ρ b d=1921.19mm^2.

ρ	R
0.011	4.17
0.0115	4.34

From table A.2:

10Φ16>> As=1940mm^2.

Check spacing: from table A.7, OK.

*As=ρ b d>> ρ = 0.01145.

ρ0.005>ρ>ρmin, OK>>Φ=0.9.

*From table A.5a:

(4.34-4.17)/ (0.0115-0.011) = (R-4.17)/ (0.01145-0.011)

R=4.323 MPa.

ρ	R
0.011	4.17
0.0115	4.34

Check Mn:

Mn=RΦbd^2=159.498 KN.m.

Mn > Mu, OK.

2.Mu=113KN.m.

Assume Φ=0.9

*R= Mu/(Φbd^2) =3.06 MPa.

*From table A.5a:

ρ	R
0.0075	2.94
0.008	3.12

(0.0095-0.009)/ (3.66-3.48) = (ρ-0.009)/ (3.57-3.48)

ρmax>ρ=0.00783>ρmin, OK.

*As=ρ b d=1327mm^2.

From table A.2:

7Φ16>> As=1393mm^2.

Check spacing: from table A.7, OK.

*As=ρ b d>> ρ = 0.00822

ρ0.005>ρ>ρmin, OK>>Φ=0.9.

*From table A.5a:

ρ	R
0.008	3.12
0.0085	3.3

(3.3-3.12)/ (0.0085-0.008) = (R-3.12)/ (0.00822-0.008)

R=3.1992 MPa.

Check Mn:

Mn=RΦbd^2=118.035 KN.m.

Mn > Mu, OK.

3.Mu=98.84KN.m.

Assume Φ=0.9

*R= Mu/(Φbd^2) =2.678MPa.

*From table A.5a:

ρ	R
0.0065	2.57
0.007	2.76

(0.007-0.0065)/ (2.76-2.57) = (ρ-0.0065)/ (2.678-2.57)

ρmax>ρ=0.0.00678>ρmin, OK.

*As=ρ b d=1149.2mm^2.

From table A.2:

6Φ16>> As=1194mm^2.

Check spacing: from table A.7, OK

*As=ρ b d>> ρ = 0.00704

ρmax>ρ>ρmin, OK>>Φ=0.9.

*From table A.5a:

ρ	R
0.007	2.76
0.0075	2.94

(2.94-2.76)/ (0.0075-0.007) = (R-2.76)/ (0.00704-0.007)

R=2.7744 MPa.

Check Mn:

Mn=RΦbd^2=102.36 KN.m.

Mn > Mu, OK.

Shear Design of beams:

B1 : (b=300mm ,d=242mm, column width =500mm):

Vu = 87.86 KN

$V_c = 0.17 * (f_c')^{1/2} * b * d = 65.3$ KN

$\phi V_c = 48.98$ KN

$\phi V_c /2 = 24.49$ KN

locate region 1 (no need shear reinforcement)

→ X1=2.25*(24.49/87.86)=**0.627m**

Distance at d (from center of column) = 0.25 + 0.242 = 0.492m

$V_{u@d} = 87.86*((2.25-0.492)/2.25)$

$V_{u@d} = 68.65$ KN $= \phi V_s + \phi V_c$

→ $V_s = 26.23$ KN $< 2*(V_c)$

$S_{max} = \min \{ A_v*f_y / 0.062 * (f_c')^{1/2} *b_w , A_v*f_y / 0.35*b_w , d/2 = 121mm , 600mm\}$

From table A.1 : Av= 2*(71)=142 mm^2

S_{max} =121 mm ~ **100 mm** → $V_{S_{max}} = A_v*f_y*d/S_{max}$ =144.33 KN

To locate region 2 (with max. space between stirrups) :

$V_u = \phi V_s + \phi V_c = 157.23$ KN $> V_{u@d} = 68.65$ KN

At S_{max} stirrups can resiste the ultimate shear – no need to special space.

→ X2 = 2.25 -0.492-X1 = **1.131 m**

# of stirrups = 1 + X2/Smax = 1 + 1.131/0.1 = 12.31 ~ 13 stirrup

<u>Vu = 101.04 KN</u>

$V_c = 0.17 *(fc')^{1/2} *b*d = 65.3$ KN

$\phi V_c = 48.98$ KN

$\phi V_c /2 = 24.49$ KN

locate region 1 (no need shear reinforcement)

→ X1=2.25*(24.49/101.04)=**0.545m**

Distance at d (from center of column) = 0.25 + 0.242 = 0.492m

$V_{u@d} = 101.04*((2.25-0.492)/2.25)$

$V_{u@d} = 78.95 \text{ KN} = \phi V_s + \phi V_c$

→ $V_s = 39.96 \text{ KN} < 2*(V_c)$

$S_{max} = \min \{ A_v*fy / 0.062 * (fc')^{1/2} *b_w , A_v*fy / 0.35*b_w , d/2 = 121mm , 600mm\}$

From table A.1 : $A_v= 2*(71)=142 \text{ mm}^2$

S_{max} =121 mm ~ **100 mm** → $V_{S_{max}} = A_v*fy*d/S_{max}$ =144.33 KN

To locate region 2 (with max. space between stirrups) :

$V_u = \phi V_s + \phi V_c = 157.23 \text{ KN} > V_{u@d} =78.95$ KN

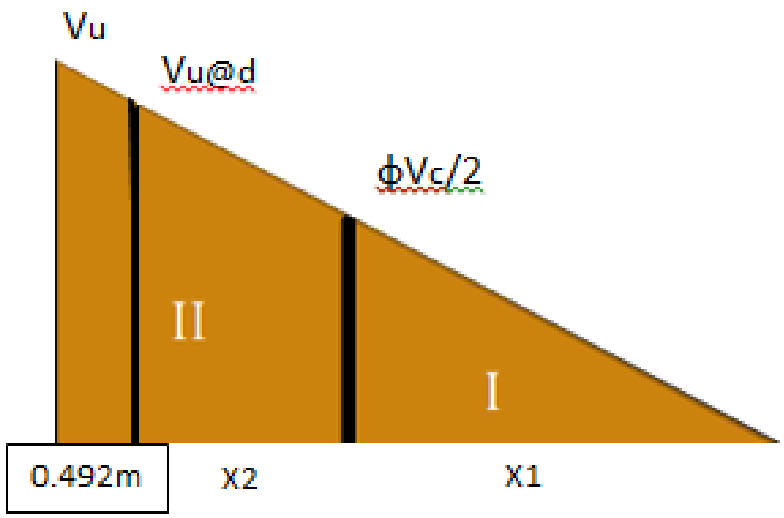
At S_{max} stirrups can resiste the ultimate shear – no need to special space.

→ X2 = 2.25 -0.492-X1 = **1.213 m**

# of stirrups = 1 + X2/Smax = 1 + 1.213/0.1 = 13.13 ~ 14 stirrup

For B1 :

Total # of stirrup = 4*13 + 2*14 = **80 stirrup**



<u>B2 : (b=700mm ,d=242mm, column width =500mm)</u>

<u>Vu = 175.72 KN</u>

$V_c = 0.17 *(fc')^{1/2} *b*d = 152.39$ KN

$\phi V_c = 114.29$ KN

$\phi V_c /2 = 57.144$ KN

locate region 1 (no need shear reinforcement)

→ X1=2.25*(57.144/175.72)=**0.732m**

Distance at d (from center of column) = 0.25 + 0.242 = 0.492m

$V_{u@d}$ = 175.72*((2.25-0.492)/2.25)

$V_{u@d}$ = 137.3 KN = $\phi V_s + \phi V_c$

→ V_s = 30.675 KN < 2*(V_c)

S_{max} = min { $A_v*fy / 0.062 * (fc')^{1/2} *b_w$, $A_v*fy / 0.35*b_w$, d/2 = 121mm , 600mm}

From table A.1 : Av= 2*(71)=142 mm^2

S_{max} =121 mm ~ **100 mm** → $V_{S_{max}} = A_v*fy*d/S_{max}$ =144.33 KN

To locate region 2 (with max. space between stirrups) :

$V_u = \phi V_s + \phi V_c$ = 222.54 KN > $V_{u@d}$ =137.3 KN

At S_{max} stirrups can resiste the ultimate shear – no need to special space.

→ X2 = 2.25 -0.492-X1 = **1.026 m**

# of stirrups = 1 + X2/Smax = 1 + 1.026/0.1 = 11.26 ~ 12 stirrup

<u>Vu = 202.08 KN</u>

$V_c = 0.17 *(fc')^{1/2} *b*d = 152.39$ KN

$\phi\ V_c = 114.29$ KN

$\phi\ V_c /2 = 57.144$ KN

locate region 1 (no need shear reinforcement)

→ X1=2.25*(57.144/202.08)=**0.636m**

Distance at d (from center of column) = 0.25 + 0.242 = 0.492m

$V_{u@d}$ = 202.08*((2.25-0.492)/2.25)

$V_{u@d}$ = 157.892 KN = $\phi\ V_s + \phi\ V_c$

→ $V_s = 58.136$ KN < $2*(V_c)$

$S_{max} = \min \{ A_v*fy / 0.062 * (fc')^{1/2} *b_w , A_v*fy / 0.35*b_w , d/2 = 121mm , 600mm\}$

From table A.1 : Av= 2*(71)=142 mm^2

S_{max} =121 mm ~ **100 mm** → $V_{S_{max}} = A_v*fy*d/S_{max}$ =144.33 KN

To locate region 2 (with max. space between stirrups) :

$V_u = \phi\ V_s + \phi\ V_c$ = 222.54 KN > $V_{u@d}$ =157.892 KN

At S_{max} stirrups can resiste the ultimate shear – no need to special space.

→ X2 = 2.25 -0.492-X1 = **1.122 m**

# of stirrups = 1 + X2/Smax = 1 + 1.122/0.1 = 12.22 ~ 13 stirrup

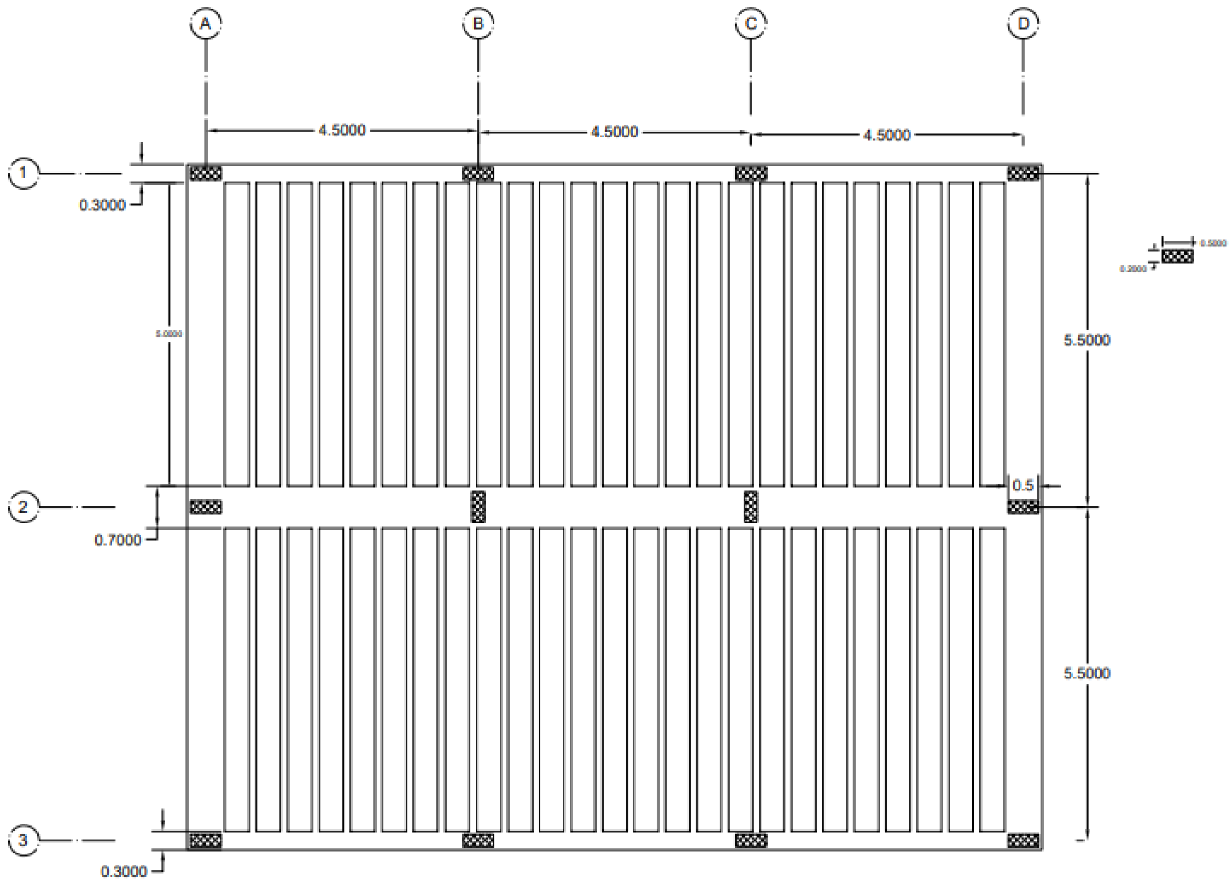
For B2 :

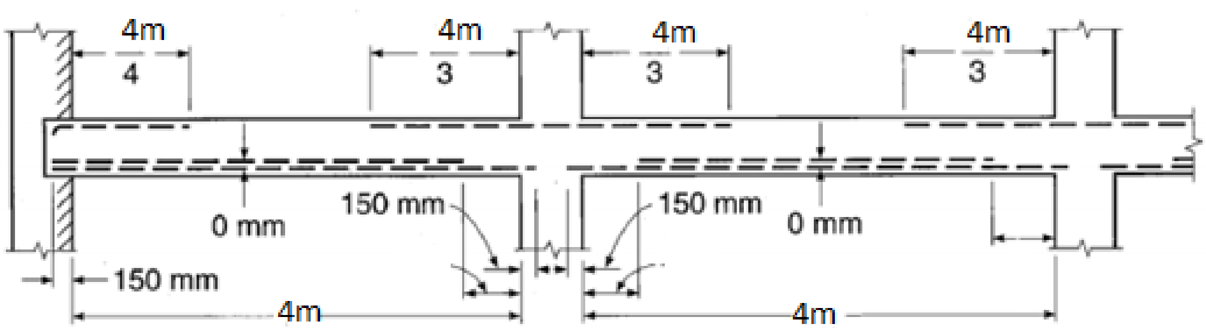
Total # of stirrup = 4*12 + 2*13 = **74 stirrup**

Practical approach : # of stirrups in B1 or B2 = 6*(2.25-0.492)/0.1 +6 = 112 stirrup

LAYOUT

Dimensions in Meter
Scale 1 : 100

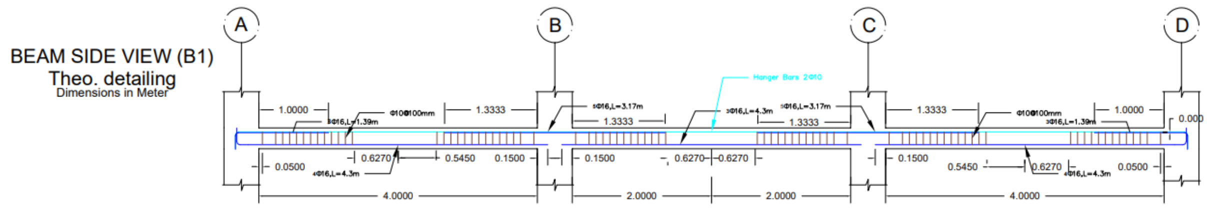


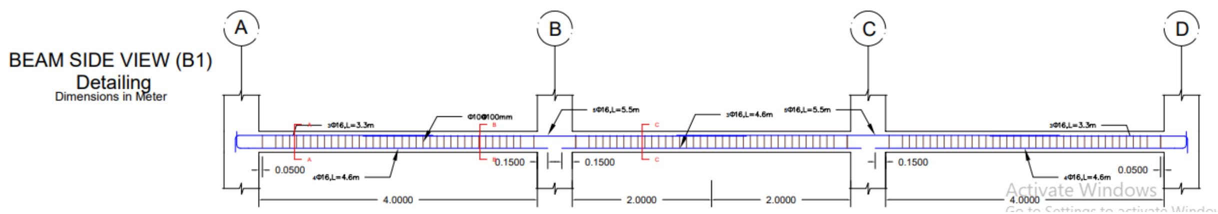


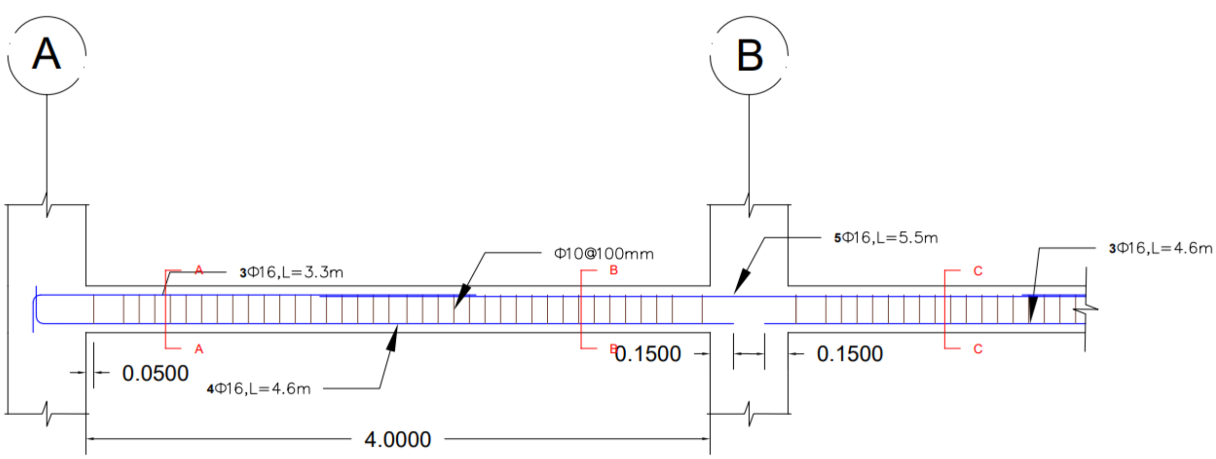
Detailing for Beams ,

side views and cross sections :

For B1 :

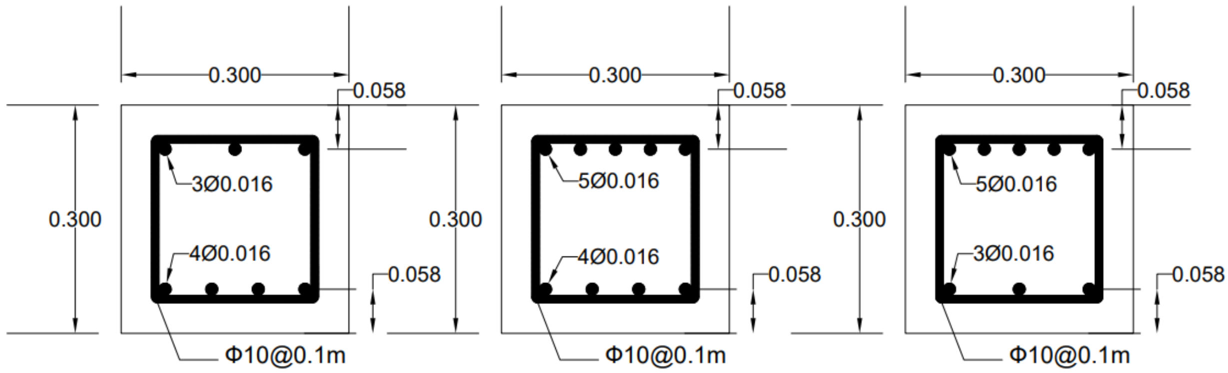






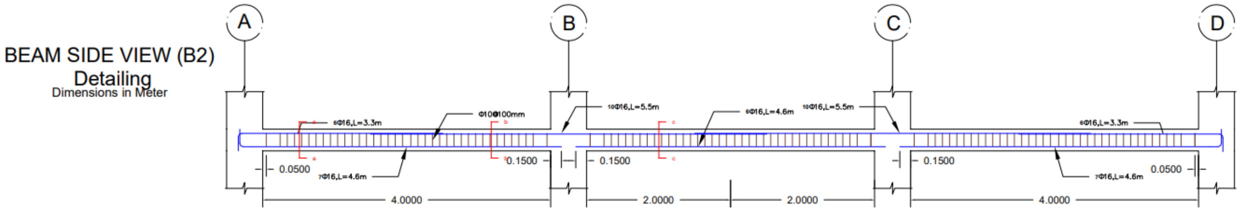
CROSS-SECTIONS (B1)

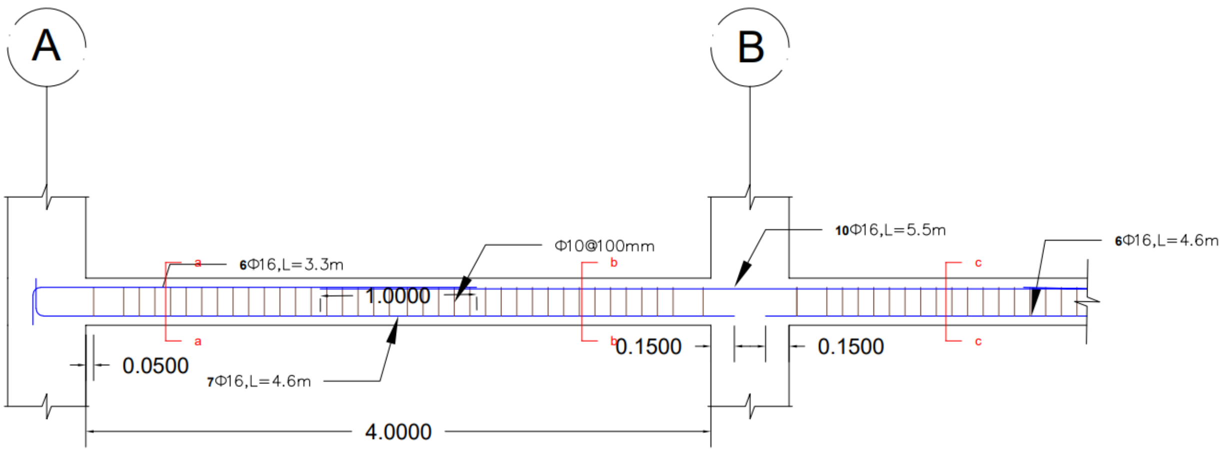
ALL DIMENSIONS IN METER



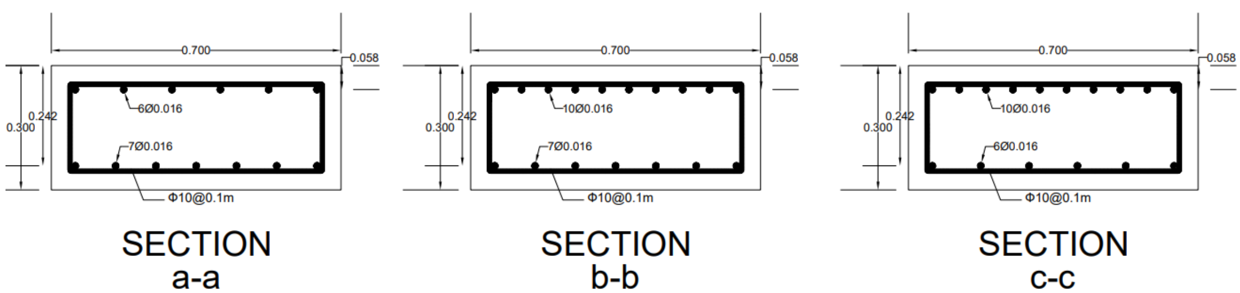
SECTION A-A | SECTION B-B | SECTION C-C

For B2:





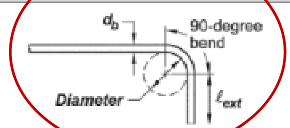
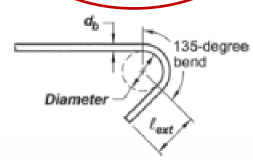
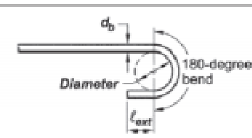
CROSS-SECTIONS (B2)
ALL DIMENSIONS IN METER



Details :

Stirrups :

Table 25.3.2—Minimum inside bend diameters and standard hook geometry for stirrups, ties, and hoops

Type of standard hook	Bar size	Minimum inside bend diameter, mm	Straight extension[1] ℓ_{ext}, mm	Type of standard hook
90-degree hook	No. 10 through No. 16	$4d_b$	Greater of $6d_b$ and 75 mm	
	No. 19 through No. 25	$6d_b$	$12d_b$	
135-degree hook	No. 10 through No. 16	$4d_b$	Greater of $6d_b$ and 75 mm	
	No. 19 through No. 25	$6d_b$		
180-degree hook	No. 10 through No. 16	$4d_b$	Greater of $4d_b$ and 65 mm	
	No. 19 through No. 25	$6d_b$		

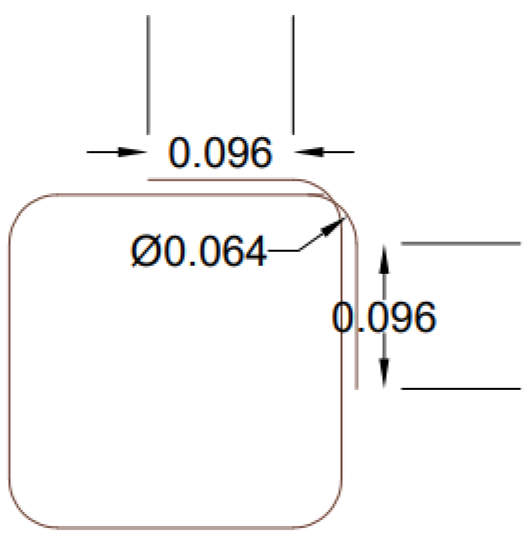
[1]A standard hook for stirrups, ties, and hoops includes the specific inside bend diameter and straight extension length. It shall be permitted to use a longer straight extension at the end of a hook. A longer extension shall not be considered to increase the anchorage capacity of the hook.

Minimum inside bend diameter = 4 *16 = 64 mm

Length of extension = max { 6*db , 75 } = 96 mm

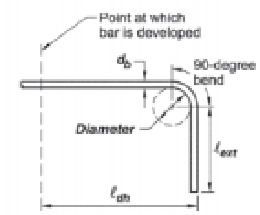
Stirrup Detail

ALL DIMENSIONS IN METER



Hook at the end of beams :

Table 25.3.1—Standard hook geometry for development of deformed bars in tension

Type of standard hook	Bar size	Minimum inside bend diameter, mm	Straight extension[1] ℓ_{ext}, mm	Type of standard hook
90-degree hook	No. 10 through No. 25	$6d_b$	$12d_b$	
	No. 29 through No. 36	$8d_b$		
	No. 43 through No. 57	$10d_b$		

Minimum inside bend diameter = 6*16 = 96mm

$L_{ext.}$ =12*16 = 192 mm

Hook Detail

ALL DIMENSIONS IN METER