GEODOMISI Ltd. - Dr. Costas Sachpazis Civil & Geotechnical Engineering Consulting Company for Structural Engineering, Soil Mechanics, Rock Mechanics, Foundation Engineering & Retaining Structures. Tel.: (+30) 210 5238127, 210 5711263 - Fax.:+30 210 5711461 - Mobile: (+30) 6936425722 & (+44) 7585939944, costas@sachpazis.info	Project: Flat Slab Analysis & Design, In accordance with BS8110:PART 1:1997				Job Ref.	
	Section Civil & Geotechnical Engineering				Sheet no./rev. 1	
	Calc. by Dr. C. Sachpazis	Date 18/01/2014	Chk'd by	Date	App'd by	Date

FLAT SLAB DESIGN TO BS8110:PART 1:1997

Slab geometry

Span of slab in x-direction; $Span_x$ = **7200** mm

Span of slab in y-direction; $Span_y$ = **7200** mm

Column dimension in x-direction; l_x = **400** mm

Column dimension in y-direction; l_y = **400** mm

External column dimension in x-direction; l_{x1} = **250** mm

External column dimension in y-direction; l_{y1} = **250** mm

Edge dimension in x-direction; $e_x = l_{x1} / 2$ = **125** mm

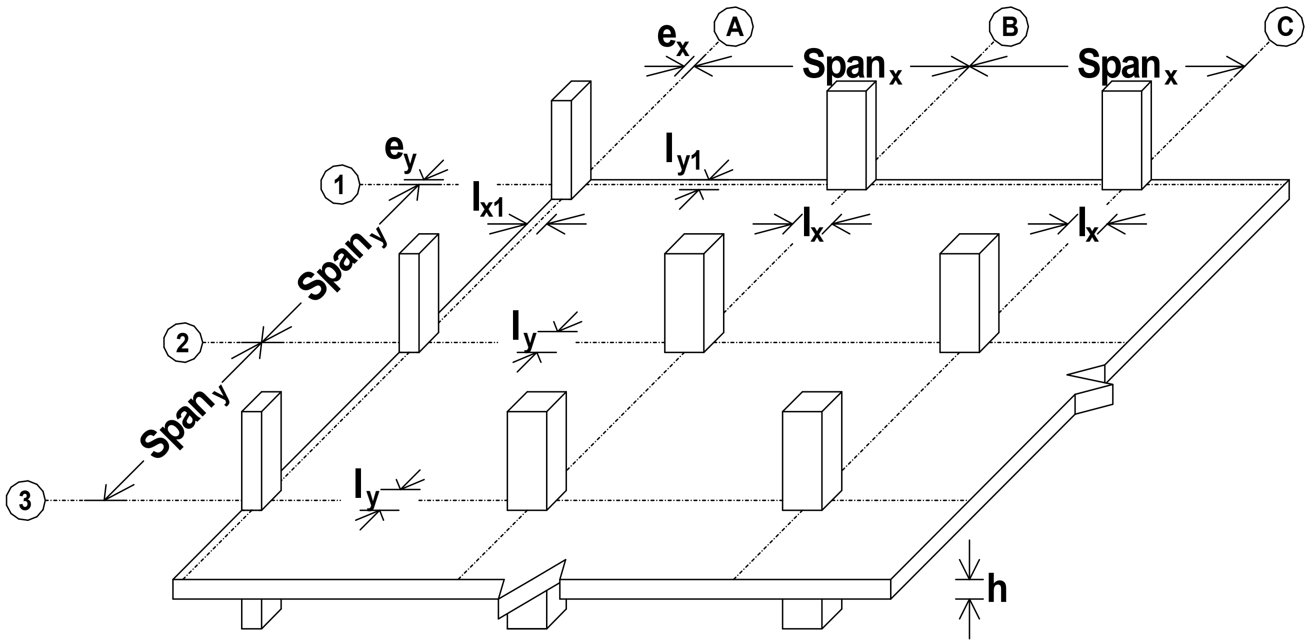
Edge dimension in y-direction; $e_y = l_{y1} / 2$ = **125** mm

Effective span of internal bay in x direction; $L_x = Span_x – l_x$ = **6800** mm

Effective span of internal bay in y direction; $L_y = Span_y – l_y$ = **6800** mm

Effective span of end bay in x direction; $L_{x1} = Span_x – l_x / 2$ = **7000** mm

Effective span of end bay in y direction; $L_{y1} = Span_y – l_y / 2$ = **7000** mm



Slab details

Depth of slab; h = **250** mm

Characteristic strength of concrete; f_{cu} = **35** N/mm^2
Characteristic strength of reinforcement; f_y = **500** N/mm^2
Characteristic strength of shear reinforcement; f_{yv} = **500** N/mm^2
Material safety factor; γ_m = **1.15**
Cover to bottom reinforcement; c = **20** mm
Cover to top reinforcement; c' = **20** mm

Loading details

Characteristic dead load; G_k = **7.000** kN/m^2
Characteristic imposed load; Q_k = **5.000** kN/m^2
Dead load factor; γ_G = **1.4**
Imposed load factor; γ_Q = **1.6**
Total ultimate load; $N_{ult} = (G_k \times \gamma_G) + (Q_k \times \gamma_Q)$ = **17.800** kN/m^2
Moment redistribution ratio; β_b = **1.0**
Ratio of support moments to span moments; i = **1.0**

DESIGN SLAB IN THE X-DIRECTION

SAGGING MOMENTS

End bay A-B

Effective span; L = **7000** mm
Depth of reinforcement; d = **200** mm
Midspan moment; $m = (N_{ult} \times L^2) / (2 \times (1 + \sqrt{(1 + i)})^2)$ = **74.823** kNm/m
Support moment; $m' = i \times m$ = **74.823** kNm/m

Design reinforcement

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2$ = **0.176**

$K = m / (d^2 \times f_{cu})$ = **0.053**

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d$ = **187.3** mm

Area of reinforcement designed; $A_{s\_des} = m / (z \times f_y / \gamma_m)$ = **919** mm^2/m
Minimum area of reinforcement required; $A_{s\_min} = 0.0013 \times h$ = **325** mm^2/m
Area of reinforcement required; $A_{s\_req} = \max(A_{s\_des}, A_{s\_min})$ = **919** mm^2/m

Provide 20 dia bars @ 150 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s)$ = **2094** mm^2/m

PASS - Span reinforcement is OK

Check deflection

Design service stress; $f_s = 2 \times f_y \times A_{s\_req} / (3 \times A_{s\_prov} \times \beta_b)$ = **146** N/mm^2
Modification factor; $k_1 = \min(0.55+(477\text{N/mm}^2-f_s)/(120\times(0.9\text{N/mm}^2+(m/d^2))),2)$ = **1.545**
Allowable span to depth ratio; $0.9 \times 26 \times k_1$ = **36.151**
Actual span to depth ratio; L / d = **35.000**

PASS - Span to depth ratio is OK

Internal bay B-C

Effective span; $L = \mathbf{6800}$ mm

Depth of reinforcement; $d = \mathbf{202}$ mm

Midspan moment; $m = (N_{ult} \times L^2) / (2 \times (\sqrt{(1 + i)} + \sqrt{(1 + i)})^2) = \mathbf{51.442}$ kNm/m

Support moment; $m' = i \times m = \mathbf{51.442}$ kNm/m

Design reinforcement

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2 = \mathbf{0.176}$

$K = m / (d^2 \times f_{cu}) = \mathbf{0.036}$

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d = \mathbf{191.9}$ mm

Area of reinforcement designed; $As_{\_des} = m / (z \times f_y / \gamma_m) = \mathbf{617}$ mm²/m

Minimum area of reinforcement required; $As_{\_min} = 0.0013 \times h = \mathbf{325}$ mm²/m

Area of reinforcement required; $As_{\_req} = \max(As_{\_des}, As_{\_min}) = \mathbf{617}$ mm²/m

Provide 16 dia bars @ 200 centres

Area of reinforcement provided; $As_{\_prov} = \pi \times D^2 / (4 \times s) = \mathbf{1005}$ mm²/m

PASS - Span reinforcement is OK

Check deflection

Design service stress; $f_s = 2 \times f_y \times As_{\_req} / (3 \times As_{\_prov} \times \beta_b) = \mathbf{204}$ N/mm²

Modification factor; $k_1 = \min(0.55+(477N/mm^2-f_s)/(120\times(0.9N/mm^2+(m/d^2))),2) = \mathbf{1.601}$

Allowable span to depth ratio; $0.9 \times 26 \times k_1 = \mathbf{37.469}$

Actual span to depth ratio; $L / d = \mathbf{33.663}$

PASS - Span to depth ratio is OK

HOGGING MOMENTS – INTERNAL STRIP

Penultimate column B3

Consider the reinforcement concentrated in half width strip over the support

Depth of reinforcement; $d' = \mathbf{200}$ mm

Support moment; $m' = 2 \times i \times m = \mathbf{149.646}$ kNm/m

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2 = \mathbf{0.176}$

$K = m' / (d'^2 \times f_{cu}) = \mathbf{0.107}$

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d' = \mathbf{172.5}$ mm

Area of reinforcement required; $As_{\_des} = m' / (z \times f_y / \gamma_m) = \mathbf{1996}$ mm²/m

Minimum area of reinforcement required; $As_{\_min} = 0.0013 \times h = \mathbf{325}$ mm²/m

Area of reinforcement required; $As_{\_req} = \max(As_{\_des}, As_{\_min}) = \mathbf{1996}$ mm²/m

Provide 20 dia bars @ 150 centres

Area of reinforcement provided; $As_{\_prov} = \pi \times D^2 / (4 \times s) = \mathbf{2094}$ mm²/m

PASS - Support reinforcement is OK

Internal column C3

Consider the reinforcement concentrated in half width strip over the support

Depth of reinforcement; $d' = \mathbf{200}$ mm

Support moment; $m' = 2 \times i \times m = \mathbf{102.884}$ kNm/m

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2 = \mathbf{0.176}$

$K = m' / (d'^2 \times f_{cu}) = \mathbf{0.073}$

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d' = \mathbf{182.1}$ mm

Area of reinforcement required; $A_{s\_des} = m' / (z \times f_y / \gamma_m) = \mathbf{1300}$ mm²/m

Minimum area of reinforcement required; $A_{s\_min} = 0.0013 \times h = \mathbf{325}$ mm²/m

Area of reinforcement required; $A_{s\_req} = \max(A_{s\_des}, A_{s\_min}) = \mathbf{1300}$ mm²/m

Provide 20 dia bars @ 200 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s) = \mathbf{1571}$ mm²/m

PASS - Support reinforcement is OK

HOGGING MOMENTS – EXTERNAL STRIP

Penultimate column B1, B2

Consider one and a half bays of negative moment being resisted over the edge and penultimate column

Width of span; $B = \mathbf{7200}$ mm

Edge distance; $e = \mathbf{125}$ mm

Depth of reinforcement; $d' = \mathbf{200}$ mm

Support moment; $m' = m \times i \times (e + B + B / 2) / ((0.5 \times B) + (0.2 \times B) + e) = \mathbf{158.265}$ kNm/m

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2 = \mathbf{0.176}$

$K = m' / (d'^2 \times f_{cu}) = \mathbf{0.113}$

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d' = \mathbf{170.5}$ mm

Area of reinforcement required; $A_{s\_des} = m' / (z \times f_y / \gamma_m) = \mathbf{2134}$ mm²/m

Minimum area of reinforcement required; $A_{s\_min} = 0.0013 \times h = \mathbf{325}$ mm²/m

Area of reinforcement required; $A_{s\_req} = \max(A_{s\_des}, A_{s\_min}) = \mathbf{2134}$ mm²/m

Provide 20 dia bars @ 125 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s) = \mathbf{2513}$ mm²/m

PASS - Support reinforcement is OK

Internal column C1, C2

Consider one and a half bays of negative moment being resisted over the edge and penultimate column

Width of span; $B = \mathbf{7200}$ mm

Edge distance; $e = \mathbf{125}$ mm

Depth of reinforcement; $d' = \mathbf{200}$ mm

Support moment; $m' = m \times i \times (e + B + B / 2) / ((0.5 \times B) + (0.2 \times B) + e) = \mathbf{108.810}$ kNm/m

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2 =$ **0.176**

$K = m' / (d'^2 \times f_{cu}) =$ **0.078**

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d' =$ **180.9** mm

Area of reinforcement required; $A_{s\_des} = m' / (z \times f_y / \gamma_m) =$ **1383** mm^2/m

Minimum area of reinforcement required; $A_{s\_min} = 0.0013 \times h =$ **325** mm^2/m

Area of reinforcement required; $A_{s\_req} = \max(A_{s\_des}, A_{s\_min}) =$ **1383** mm^2/m

Provide 20 dia bars @ 200 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s) =$ **1571** mm^2/m

PASS - Support reinforcement is OK

<u>Corner column A1</u>

Depth of reinforcement; $d' =$ **206** mm

Total load on column; $S = ((Span_x / 2) + e_x) \times ((Span_y / 2) + e_y) \times N_{ult} =$ **247** kN

Area of column head; $A = l_x \times l_{y1} =$ **0.100** m^2

Support moment; $m' = S \times (1 - (N_{ult} \times A / S)^{1/3}) / 2 =$ **99.639** kNm/m

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2 =$ **0.176**

$K = m' / (d'^2 \times f_{cu}) =$ **0.067**

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d' =$ **189.3** mm

Area of reinforcement required; $A_{s\_des} = m' / (z \times f_y / \gamma_m) =$ **1211** mm^2/m

Minimum area of reinforcement required; $A_{s\_min} = 0.0013 \times h =$ **325** mm^2/m

Area of reinforcement required; $A_{s\_req} = \max(A_{s\_des}, A_{s\_min}) =$ **1211** mm^2/m

Provide 16 dia bars @ 150 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s) =$ **1340** mm^2/m

PASS - Support reinforcement is OK

<u>Edge column A2, A3</u>

Depth of reinforcement; $d' =$ **202** mm

Total load on column; $S = Span_x \times (Span_y / 2 + e_y) \times N_{ult} =$ **477** kN

Area of column head; $A = l_{x1} \times l_y =$ **0.100** m^2

Support moment; $m' = S \times (1 - (N_{ult} \times A / S)^{1/3}) / 5.14 =$ **78.476** kNm/m

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2 =$ **0.176**

$K = m' / (d'^2 \times f_{cu}) =$ **0.055**

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d' =$ **188.8** mm

Area of reinforcement required; $A_{s\_des} = m' / (z \times f_y / \gamma_m) =$ **956** mm^2/m

Minimum area of reinforcement required; $A_{s\_min} = 0.0013 \times h =$ **325** mm^2/m

Area of reinforcement required; $A_{s\_req} = \max(A_{s\_des}, A_{s\_min}) =$ **956** mm^2/m

Provide 16 dia bars @ 175 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s) =$ **1149** mm^2/m

PASS - Support reinforcement is OK

Between columns 1-2, 2-3

Around the perimeter between the column heads provide a minimum of 50% of the required end span bottom reinforcement.

Area of reinforcement required; $A_{s\_req} = A_{sx1} / 2 = \mathbf{1047}$ mm^2/m

Provide 16 dia bars @ 150 centres - 'U' bars with 1600 mm long legs

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s) = \mathbf{1340}$ mm^2/m

PASS - Edge reinforcement is OK

Distribution reinforcement

Provide 12 dia bars @ 300 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s) = \mathbf{377}$ mm^2/m

DESIGN SLAB IN THE Y-DIRECTION

SAGGING MOMENTS

End bay 1-2

Effective span; L = **7000** mm

Depth of reinforcement; d = **220** mm

Midspan moment; $m = (N_{ult} \times L^2) / (2 \times (1 + \sqrt{(1 + i)})^2) = \mathbf{74.823}$ kNm/m

Support moment; $m' = i \times m = \mathbf{74.823}$ kNm/m

Design reinforcement

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2 = \mathbf{0.176}$

$K = m / (d^2 \times f_{cu}) = \mathbf{0.044}$

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d = \mathbf{208.6}$ mm

Area of reinforcement designed; $A_{s\_des} = m / (z \times f_y / \gamma_m) = \mathbf{825}$ mm^2/m

Minimum area of reinforcement required; $A_{s\_min} = 0.0013 \times h = \mathbf{325}$ mm^2/m

Area of reinforcement required; $A_{s\_req} = \max(A_{s\_des}, A_{s\_min}) = \mathbf{825}$ mm^2/m

Provide 20 dia bars @ 200 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s) = \mathbf{1571}$ mm^2/m

PASS - Span reinforcement is OK

Check deflection

Design service stress; $f_s = 2 \times f_y \times A_{s\_req} / (3 \times A_{s\_prov} \times \beta_b) = \mathbf{175}$ N/mm^2

Modification factor; $k_1 = \min(0.55+(477N/mm^2-f_s)/(120\times(0.9N/mm^2+(m/d^2))),2) = \mathbf{1.579}$

Allowable span to depth ratio; $0.9 \times 26 \times k_1 = \mathbf{36.942}$

Actual span to depth ratio; $L / d = \mathbf{31.818}$

PASS - Span to depth ratio is OK

Internal bay 2-3

Effective span; L = **6800** mm

Depth of reinforcement; $d = \mathbf{222}$ mm

Midspan moment; $m = (N_{ult} \times L^2) / (2 \times (\sqrt{(1 + i)} + \sqrt{(1 + i)})^2) = \mathbf{51.442}$ kNm/m

Support moment; $m' = i \times m = \mathbf{51.442}$ kNm/m

Design reinforcement

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2 = \mathbf{0.176}$

$K = m / (d^2 \times f_{cu}) = \mathbf{0.030}$

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d = \mathbf{210.9}$ mm

Area of reinforcement designed; $A_{s\_des} = m / (z \times f_y / \gamma_m) = \mathbf{561}$ mm²/m

Minimum area of reinforcement required; $A_{s\_min} = 0.0013 \times h = \mathbf{325}$ mm²/m

Area of reinforcement required; $A_{s\_req} = \max(A_{s\_des}, A_{s\_min}) = \mathbf{561}$ mm²/m

Provide 16 dia bars @ 200 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s) = \mathbf{1005}$ mm²/m

PASS - Span reinforcement is OK

Check deflection

Design service stress; $f_s = 2 \times f_y \times A_{s\_req} / (3 \times A_{s\_prov} \times \beta_b) = \mathbf{186}$ N/mm²

Modification factor; $k_1 = \min(0.55+(477N/mm^2-f_s)/(120\times(0.9N/mm^2+(m/d^2))),2) = \mathbf{1.798}$

Allowable span to depth ratio; $0.9 \times 26 \times k_1 = \mathbf{42.062}$

Actual span to depth ratio; $L / d = \mathbf{30.631}$

PASS - Span to depth ratio is OK

<u>HOGGING MOMENTS – INTERNAL STRIP</u>

<u>Penultimate column C2</u>

Consider the reinforcement concentrated in half width strip over the support

Depth of reinforcement; $d' = \mathbf{220}$ mm

Support moment; $m' = 2 \times i \times m = \mathbf{149.646}$ kNm/m

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2 = \mathbf{0.176}$

$K = m' / (d'^2 \times f_{cu}) = \mathbf{0.088}$

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d' = \mathbf{195.7}$ mm

Area of reinforcement required; $A_{s\_des} = m' / (z \times f_y / \gamma_m) = \mathbf{1758}$ mm²/m

Minimum area of reinforcement required; $A_{s\_min} = 0.0013 \times h = \mathbf{325}$ mm²/m

Area of reinforcement required; $A_{s\_req} = \max(A_{s\_des}, A_{s\_min}) = \mathbf{1758}$ mm²/m

Provide 20 dia bars @ 150 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s) = \mathbf{2094}$ mm²/m

PASS - Support reinforcement is OK

<u>Internal column C3</u>

Consider the reinforcement concentrated in half width strip over the support

Depth of reinforcement; $d' = \mathbf{220}$ mm

Support moment; $m' = 2 \times i \times m$ = **102.884** kNm/m

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2$ = **0.176**

$K = m' / (d'^2 \times f_{cu})$ = **0.061**

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d'$ = **204.0** mm

Area of reinforcement required; $A_{s\_des} = m' / (z \times f_y / \gamma_m)$ = **1160** mm^2/m

Minimum area of reinforcement required; $A_{s\_min} = 0.0013 \times h$ = **325** mm^2/m

Area of reinforcement required; $A_{s\_req} = \max(A_{s\_des}, A_{s\_min})$ = **1160** mm^2/m

Provide 20 dia bars @ 200 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s)$ = **1571** mm^2/m

PASS - Support reinforcement is OK

HOGGING MOMENTS – EXTERNAL STRIP

Penultimate column A2, B2

Consider one and a half bays of negative moment being resisted over the edge and penultimate column

Width of span; B = **7200** mm

Edge distance; e = **125** mm

Depth of reinforcement; d' = **220** mm

Support moment; $m' = m \times i \times (e + B + B / 2) / ((0.5 \times B) + (0.2 \times B) + e)$ = **158.265** kNm/m

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2$ = **0.176**

$K = m' / (d'^2 \times f_{cu})$ = **0.093**

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d'$ = **194.1** mm

Area of reinforcement required; $A_{s\_des} = m' / (z \times f_y / \gamma_m)$ = **1875** mm^2/m

Minimum area of reinforcement required; $A_{s\_min} = 0.0013 \times h$ = **325** mm^2/m

Area of reinforcement required; $A_{s\_req} = \max(A_{s\_des}, A_{s\_min})$ = **1875** mm^2/m

Provide 20 dia bars @ 150 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s)$ = **2094** mm^2/m

PASS - Support reinforcement is OK

Internal column A3, B3

Consider one and a half bays of negative moment being resisted over the edge and penultimate column

Width of span; B = **7200** mm

Edge distance; e = **125** mm

Depth of reinforcement; d' = **220** mm

Support moment; $m' = m \times i \times (e + B + B / 2) / ((0.5 \times B) + (0.2 \times B) + e)$ = **108.810** kNm/m

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2$ = **0.176**

$K = m' / (d'^2 \times f_{cu})$ = **0.064**

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d' =$ **203.0** mm

Area of reinforcement required; $A_{s\_des} = m' / (z \times f_y / \gamma_m) =$ **1233** mm^2/m

Minimum area of reinforcement required; $A_{s\_min} = 0.0013 \times h =$ **325** mm^2/m

Area of reinforcement required; $A_{s\_req} = \max(A_{s\_des}, A_{s\_min}) =$ **1233** mm^2/m

Provide 20 dia bars @ 200 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s) =$ **1571** mm^2/m

PASS - Support reinforcement is OK

Edge column B1, C1

Depth of reinforcement; $d' =$ **222** mm

Total load on column; $S = (Span_x / 2 + e_x) \times Span_y \times N_{ult} =$ **477** kN

Area of column head; $A = l_{y1} \times l_x =$ **0.100** m^2

Support moment; $m' = S \times (1 - (N_{ult} \times A / S)^{1/3}) / 5.14 =$ **78.476** kNm/m

Lever arm; $K' = 0.402 \times (\beta_b - 0.4) - 0.18 \times (\beta_b - 0.4)^2 =$ **0.176**

$K = m' / (d'^2 \times f_{cu}) =$ **0.045**

Compression reinforcement is not required

$z = \min((0.5 + \sqrt{(0.25 - (K / 0.9))}), 0.95) \times d' =$ **210.1** mm

Area of reinforcement required; $A_{s\_des} = m' / (z \times f_y / \gamma_m) =$ **859** mm^2/m

Minimum area of reinforcement required; $A_{s\_min} = 0.0013 \times h =$ **325** mm^2/m

Area of reinforcement required; $A_{s\_req} = \max(A_{s\_des}, A_{s\_min}) =$ **859** mm^2/m

Provide 16 dia bars @ 175 centres

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s) =$ **1149** mm^2/m

PASS - Support reinforcement is OK

Between columns A-B, B-C

Around the perimeter between the column heads provide a minimum of 50% of the required end span bottom reinforcement.

Area of reinforcement required; $A_{s\_req} = A_{sy1} / 2 =$ **785** mm^2/m

Provide 16 dia bars @ 200 centres - 'U' bars with 1600 mm long legs

Area of reinforcement provided; $A_{s\_prov} = \pi \times D^2 / (4 \times s) =$ **1005** mm^2/m

PASS - Edge reinforcement is OK

PUNCHING SHEAR

Corner column A1

Design shear transferred to column; $V_t = ((0.45 \times Span_x) + e_x) \times ((0.45 \times Span_y) + e_y) \times N_{ult} =$ **202** kN

Design effective shear transferred to column; $V_{eff} = 1.25 \times V_t =$ **252** kN

Area of tension steel in x-direction; $A_{sx\_ten} = A_{scorner} =$ **1340** mm^2/m

Area of tension steel in y-direction; $A_{sy\_ten} = A_{scorner} =$ **1340** mm^2/m

Column perimeter; $u_c = l_{x1} + l_y =$ **650** mm

Average effective depth of reinforcement; $d = h - c - \phi_p =$ **214** mm

Maximum allowable shear stress; v_{max} = min(0.8 × √(f_{cu}), 5) = **4.733** N/mm^2

Design shear stress at column perimeter; v_0 = V_{eff} / (u_c × d) = **1.811** N/mm^2

PASS - Maximum concrete shear stress not exceeded at column perimeter

Shear reinforcement at a perimeter of 1.50d - (321 mm)

Length of shear perimeter; u = u_c + (2 × (k_x × k_y) × k × d) = **1292** mm

Area of tension steel at shear perimeter; A_{s_ten} = (k_y × (p_x + (k_x × k × d)) × A_{sy_ten}) + (k_x × (p_y + (k_y × k × d)) × A_{sx_ten})

A_{s_ten} = **1731** mm^2

Design concrete shear stress;

v_c=(min(f_{cu},40)/25)$^{1/3}$×0.79×min(100×A_{s_ten}/(u×d),3)$^{1/3}$×max(400/d,1)$^{1/4}$/1.25

v_c = **0.707** N/mm^2

Nominal design shear stress at perimeter; v = V_{eff} / (u × d) = **0.911** N/mm^2

v_c < v <= 1.6 × v_c

Shear reinforcement required at perimeter; A_{sv_req} = (v - v_c) × u × d / (0.95 × f_{yv}) = **119** mm^2

Shear reinforcement at a perimeter of 2.25d - (482 mm)

Length of shear perimeter; u = u_c + (2 × (k_x × k_y) × k × d) = **1613** mm

Area of tension steel at shear perimeter; A_{s_ten} = (k_y × (p_x + (k_x × k × d)) × A_{sy_ten}) + (k_x × (p_y + (k_y × k × d)) × A_{sx_ten})

A_{s_ten} = **2161** mm^2

Design concrete shear stress;

v_c=(min(f_{cu},40)/25)$^{1/3}$×0.79×min(100×A_{s_ten}/(u×d),3)$^{1/3}$×max(400/d,1)$^{1/4}$/1.25

v_c = **0.707** N/mm^2

Nominal design shear stress at perimeter; v = V_{eff} / (u × d) = **0.730** N/mm^2

v_c < v <= 1.6 × v_c

Shear reinforcement required at perimeter; A_{sv_req} = (v - v_c) × u × d / (0.95 × f_{yv}) = **16** mm^2

Shear reinforcement at a perimeter of 3.00d - (642 mm)

Length of shear perimeter; u = u_c + (2 × (k_x × k_y) × k × d) = **1934** mm

Area of tension steel at shear perimeter; A_{s_ten} = (k_y × (p_x + (k_x × k × d)) × A_{sy_ten}) + (k_x × (p_y + (k_y × k × d)) × A_{sx_ten})

A_{s_ten} = **2592** mm^2

Design concrete shear stress;

v_c=(min(f_{cu},40)/25)$^{1/3}$×0.79×min(100×A_{s_ten}/(u×d),3)$^{1/3}$×max(400/d,1)$^{1/4}$/1.25

v_c = **0.707** N/mm^2

Nominal design shear stress at perimeter; v = V_{eff} / (u × d) = **0.609** N/mm^2

v < v_c no shear reinforcement required

<u>**Penultimate edge column A2**</u>

Design shear transferred to column; V_t = ((0.45 × $Span_x$) + e_x) × (1.05 × $Span_y$) × N_{ult} = **453** kN

Design effective shear transferred to column; V_{eff} = 1.4 × V_t = **634** kN

Area of tension steel in x-direction; A_{sx_ten} = A_{sx_edge} = **1148** mm^2/m

Area of tension steel in y-direction; $A_{sy\_ten} = A_{sy1e}$ = **2094** mm^2/m

Column perimeter; $u_c = (2 \times l_{x1}) + l_y$ = **900** mm

Average effective depth of reinforcement; $d = h - c - \phi_p$ = **214** mm

Maximum allowable shear stress; $v_{max} = \min(0.8 \times \sqrt{(f_{cu})}, 5)$ = **4.733** N/mm^2

Design shear stress at column perimeter; $v_0 = V_{eff} / (u_c \times d)$ = **3.292** N/mm^2

PASS - Maximum concrete shear stress not exceeded at column perimeter

Shear reinforcement at a perimeter of 1.50d - (321 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **2184** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **3588** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

v_c = **0.757** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **1.356** N/mm^2

$1.6 \times v_c < v <= 2 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = 5 \times ((0.7 \times v) - v_c) \times u \times d / (0.95 \times f_{yv})$ = **947** mm^2

Shear reinforcement at a perimeter of 2.25d - (482 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **2826** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **4628** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

v_c = **0.756** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **1.048** N/mm^2

$v_c < v <= 1.6 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv})$ = **372** mm^2

Shear reinforcement at a perimeter of 3.00d - (642 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **3468** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **5669** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

v_c = **0.756** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **0.854** N/mm^2

$v_c < v <= 1.6 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv})$ = **154** mm^2

Shear reinforcement at a perimeter of 3.75d - (803 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d) =$ **4110** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

$A_{s\_ten} =$ **6710** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times 0.79\times \min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times \max(400/d,1)^{1/4}/1.25$

$v_c =$ **0.755** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d) =$ **0.721** N/mm^2

$v < v_c$ no shear reinforcement required

<u>Internal edge column A3</u>

Design shear transferred to column; $V_t = ((0.45 \times Span_x) + e_x) \times Span_y \times N_{ult} =$ **431** kN

Design effective shear transferred to column; $V_{eff} = 1.4 \times V_t =$ **604** kN

Area of tension steel in x-direction; $A_{sx\_ten} = A_{sx\_edge} =$ **1148** mm^2/m

Area of tension steel in y-direction; $A_{sy\_ten} = A_{sye} =$ **1570** mm^2/m

Column perimeter; $u_c = (2 \times l_{x1}) + l_y =$ **900** mm

Average effective depth of reinforcement; $d = h - c - \phi_p =$ **214** mm

Maximum allowable shear stress; $v_{max} = \min(0.8 \times \sqrt{(f_{cu})}, 5) =$ **4.733** N/mm^2

Design shear stress at column perimeter; $v_0 = V_{eff} / (u_c \times d) =$ **3.135** N/mm^2

PASS - Maximum concrete shear stress not exceeded at column perimeter

Shear reinforcement at a perimeter of 1.50d - (321 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d) =$ **2184** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

$A_{s\_ten} =$ **2989** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times 0.79\times \min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times \max(400/d,1)^{1/4}/1.25$

$v_c =$ **0.712** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d) =$ **1.292** N/mm^2

$1.6 \times v_c < v <= 2 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = 5 \times ((0.7 \times v) - v_c) \times u \times d / (0.95 \times f_{yv}) =$ **945** mm^2

Shear reinforcement at a perimeter of 2.25d - (482 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d) =$ **2826** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

$A_{s\_ten} =$ **3862** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times 0.79\times \min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times \max(400/d,1)^{1/4}/1.25$

$v_c =$ **0.712** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d) = \mathbf{0.998}$ N/mm^2

$v_c < v <= 1.6 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv}) = \mathbf{365}$ mm^2

Shear reinforcement at a perimeter of 3.00d - (642 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d) = \mathbf{3468}$ mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

$A_{s\_ten} = \mathbf{4734}$ mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

$v_c = \mathbf{0.712}$ N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d) = \mathbf{0.814}$ N/mm^2

$v_c < v <= 1.6 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv}) = \mathbf{159}$ mm^2

Shear reinforcement at a perimeter of 3.75d - (803 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d) = \mathbf{4110}$ mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

$A_{s\_ten} = \mathbf{5607}$ mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

$v_c = \mathbf{0.711}$ N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d) = \mathbf{0.686}$ N/mm^2

$v < v_c$ no shear reinforcement required

<u>Penultimate edge column B1</u>

Design shear transferred to column; $V_t = (1.05 \times Span_x) \times ((0.45 \times Span_y) + e_y) \times N_{ult} = \mathbf{453}$ kN

Design effective shear transferred to column; $V_{eff} = 1.4 \times V_t = \mathbf{634}$ kN

Area of tension steel in x-direction; $A_{sx\_ten} = A_{sx1e} = \mathbf{2513}$ mm^2/m

Area of tension steel in y-direction; $A_{sy\_ten} = A_{sy\_edge} = \mathbf{1148}$ mm^2/m

Column perimeter; $u_c = l_x + (2 \times l_{y1}) = \mathbf{900}$ mm

Average effective depth of reinforcement; $d = h - c - \phi_p = \mathbf{214}$ mm

Maximum allowable shear stress; $v_{max} = \min(0.8 \times \sqrt{(f_{cu})}, 5) = \mathbf{4.733}$ N/mm^2

Design shear stress at column perimeter; $v_0 = V_{eff} / (u_c \times d) = \mathbf{3.292}$ N/mm^2

PASS - Maximum concrete shear stress not exceeded at column perimeter

Shear reinforcement at a perimeter of 1.50d - (321 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d) = \mathbf{2184}$ mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

$A_{s\_ten} = \mathbf{4066}$ mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

v_c = **0.789** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **1.356** N/mm^2

$1.6 \times v_c < v <= 2 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = 5 \times ((0.7 \times v) - v_c) \times u \times d / (0.95 \times f_{yv})$ = **789** mm^2

Shear reinforcement at a perimeter of 2.25d - (482 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **2826** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **5241** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

v_c = **0.788** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **1.048** N/mm^2

$v_c < v <= 1.6 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv})$ = **331** mm^2

Shear reinforcement at a perimeter of 3.00d - (642 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **3468** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **6416** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

v_c = **0.788** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **0.854** N/mm^2

$v_c < v <= 1.6 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv})$ = **104** mm^2

Shear reinforcement at a perimeter of 3.75d - (803 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **4110** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **7592** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

v_c = **0.787** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **0.721** N/mm^2

$v < v_c$ no shear reinforcement required

Penultimate central column B2

Design shear transferred to column; $V_t = (1.05 \times Span_x) \times (1.05 \times Span_y) \times N_{ult}$ = **1017** kN

Design effective shear transferred to column; $V_{eff} = 1.15 \times V_t$ = **1170** kN

Area of tension steel in x-direction; $A_{sx\_ten} = A_{sx1e}$ = **2513** mm^2/m

Area of tension steel in y-direction; $A_{sy\_ten} = A_{sy1e}$ = **2094** mm^2/m

Column perimeter; $u_c = 2 \times (l_x + l_y)$ = **1600** mm

Average effective depth of reinforcement; $d = h - c - \phi_p$ = **214** mm

Maximum allowable shear stress; $v_{max} = \min(0.8 \times \sqrt{(f_{cu})}, 5)$ = **4.733** N/mm^2

Design shear stress at column perimeter; $v_0 = V_{eff} / (u_c \times d)$ = **3.417** N/mm^2

PASS - Maximum concrete shear stress not exceeded at column perimeter

Shear reinforcement at a perimeter of 1.50d - (321 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **4168** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **9601** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

v_c = **0.847** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **1.312** N/mm^2

$\mathbf{v_c < v <= 1.6 \times v_c}$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv})$ = **872** mm^2

Shear reinforcement at a perimeter of 2.25d - (482 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **5452** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **12559** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

v_c = **0.847** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **1.003** N/mm^2

$\mathbf{v_c < v <= 1.6 \times v_c}$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv})$ = **382** mm^2

Shear reinforcement at a perimeter of 3.00d - (642 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **6736** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **15516** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

v_c = **0.847** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **0.812** N/mm^2

$v < v_c$ no shear reinforcement required

<u>Internal central column B3</u>

Design shear transferred to column; $V_t = (1.05 \times Span_x) \times Span_y \times N_{ult}$ = **969** kN

Design effective shear transferred to column; $V_{eff} = 1.15 \times V_t$ = **1114** kN

Area of tension steel in x-direction; $A_{sx\_ten} = A_{sx1i}$ = **2094** mm^2/m

Area of tension steel in y-direction; $A_{sy\_ten} = A_{sye}$ = **1570** mm^2/m

Column perimeter; $u_c = 2 \times (l_x + l_y)$ = **1600** mm

Average effective depth of reinforcement; $d = h - c - \phi_p$ = **214** mm

Maximum allowable shear stress; $v_{max} = \min(0.8 \times \sqrt{(f_{cu})}, 5)$ = **4.733** N/mm^2

Design shear stress at column perimeter; $v_0 = V_{eff} / (u_c \times d)$ = **3.254** N/mm^2

PASS - Maximum concrete shear stress not exceeded at column perimeter

Shear reinforcement at a perimeter of 1.50d - (321 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **4168** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **7636** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

v_c = **0.785** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **1.249** N/mm^2

$v_c < v <= 1.6 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv})$ = **872** mm^2

Shear reinforcement at a perimeter of 2.25d - (482 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **5452** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **9988** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

v_c = **0.785** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **0.955** N/mm^2

$v_c < v <= 1.6 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv})$ = **418** mm^2

Shear reinforcement at a perimeter of 3.00d - (642 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **6736** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **12340** mm^2

Design concrete shear stress;

v_c=(min(f_{cu},40)/25)$^{1/3}$×0.79×min(100×A_{s_ten}/(u×d),3)$^{1/3}$×max(400/d,1)$^{1/4}$/1.25

v_c = **0.785** N/mm^2

Nominal design shear stress at perimeter; v = V_{eff} / (u × d) = **0.773** N/mm^2

v < v_c no shear reinforcement required

<u>Internal edge column C1</u>

Design shear transferred to column; V_t = $Span_x$ × ((0.45 × $Span_y$) + e_y) × N_{ult} = **431** kN

Design effective shear transferred to column; V_{eff} = 1.4 × V_t = **604** kN

Area of tension steel in x-direction; A_{sx_ten} = A_{sxe} = **1570** mm^2/m

Area of tension steel in y-direction; A_{sy_ten} = A_{sy_edge} = **1148** mm^2/m

Column perimeter; u_c = l_x + (2 × l_{y1}) = **900** mm

(Library item: Flat slab shear map C1) Average effective depth of reinforcement; d = h – c - ϕ_p = **214** mm

Maximum allowable shear stress; v_{max} = min(0.8 × √(f_{cu}), 5) = **4.733** N/mm^2

Design shear stress at column perimeter; v_0 = V_{eff} / (u_c × d) = **3.135** N/mm^2

PASS - Maximum concrete shear stress not exceeded at column perimeter

Shear reinforcement at a perimeter of 1.50d - (321 mm)

Length of shear perimeter; u = u_c + (2 × (k_x × k_y) × k × d) = **2184** mm

Area of tension steel at shear perimeter; A_{s_ten} = (k_y × (p_x + (k_x × k × d)) × A_{sy_ten}) + (k_x × (p_y + (k_y × k × d)) × A_{sx_ten})

A_{s_ten} = **2989** mm^2

Design concrete shear stress;

v_c=(min(f_{cu},40)/25)$^{1/3}$×0.79×min(100×A_{s_ten}/(u×d),3)$^{1/3}$×max(400/d,1)$^{1/4}$/1.25

v_c = **0.712** N/mm^2

Nominal design shear stress at perimeter; v = V_{eff} / (u × d) = **1.292** N/mm^2

1.6 × v_c < v <= 2 × v_c

Shear reinforcement required at perimeter; A_{sv_req} = 5 × ((0.7 × v) - v_c) × u × d / (0.95 × f_{yv}) = **945** mm^2

Shear reinforcement at a perimeter of 2.25d - (482 mm)

Length of shear perimeter; u = u_c + (2 × (k_x × k_y) × k × d) = **2826** mm

Area of tension steel at shear perimeter; A_{s_ten} = (k_y × (p_x + (k_x × k × d)) × A_{sy_ten}) + (k_x × (p_y + (k_y × k × d)) × A_{sx_ten})

A_{s_ten} = **3862** mm^2

Design concrete shear stress;

v_c=(min(f_{cu},40)/25)$^{1/3}$×0.79×min(100×A_{s_ten}/(u×d),3)$^{1/3}$×max(400/d,1)$^{1/4}$/1.25

v_c = **0.712** N/mm^2

Nominal design shear stress at perimeter; v = V_{eff} / (u × d) = **0.998** N/mm^2

v_c < v <= 1.6 × v_c

Shear reinforcement required at perimeter; A_{sv_req} = (v - v_c) × u × d / (0.95 × f_{yv}) = **365** mm^2

Shear reinforcement at a perimeter of 3.00d - (642 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d) = \mathbf{3468}$ mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

$A_{s\_ten} = \mathbf{4734}$ mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

$v_c = \mathbf{0.712}$ N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d) = \mathbf{0.814}$ N/mm^2

$\mathbf{v_c < v <= 1.6 \times v_c}$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv}) = \mathbf{159}$ mm^2

Shear reinforcement at a perimeter of 3.75d - (803 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d) = \mathbf{4110}$ mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

$A_{s\_ten} = \mathbf{5607}$ mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

$v_c = \mathbf{0.711}$ N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d) = \mathbf{0.686}$ N/mm^2

$v < v_c$ no shear reinforcement required

<u>Internal central column C2</u>

Design shear transferred to column; $V_t = Span_x \times (1.05 \times Span_y) \times N_{ult} = \mathbf{969}$ kN

Design effective shear transferred to column; $V_{eff} = 1.15 \times V_t = \mathbf{1114}$ kN

Area of tension steel in x-direction; $A_{sx\_ten} = A_{sxe} = \mathbf{1570}$ mm^2/m

Area of tension steel in y-direction; $A_{sy\_ten} = A_{sy1i} = \mathbf{2094}$ mm^2/m

Column perimeter; $u_c = 2 \times (l_x + l_y) = \mathbf{1600}$ mm

Average effective depth of reinforcement; $d = h – c - \phi_p = \mathbf{214}$ mm

Maximum allowable shear stress; $v_{max} = \min(0.8 \times \sqrt{(f_{cu})}, 5) = \mathbf{4.733}$ N/mm^2

Design shear stress at column perimeter; $v_0 = V_{eff} / (u_c \times d) = \mathbf{3.254}$ N/mm^2

PASS - Maximum concrete shear stress not exceeded at column perimeter

Shear reinforcement at a perimeter of 1.50d - (321 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d) = \mathbf{4168}$ mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

$A_{s\_ten} = \mathbf{7636}$ mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times0.79\times\min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times\max(400/d,1)^{1/4}/1.25$

$v_c = \mathbf{0.785}$ N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d) = \mathbf{1.249}$ N/mm^2

$v_c < v <= 1.6 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv})$ = **872** mm^2

Shear reinforcement at a perimeter of 2.25d - (482 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **5452** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **9988** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times 0.79\times \min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times \max(400/d,1)^{1/4}/1.25$

v_c = **0.785** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **0.955** N/mm^2

$v_c < v <= 1.6 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv})$ = **418** mm^2

Shear reinforcement at a perimeter of 3.00d - (642 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **6736** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **12340** mm^2

Design concrete shear stress;

$v_c=(\min(f_{cu},40)/25)^{1/3}\times 0.79\times \min(100\times A_{s\_ten}/(u\times d),3)^{1/3}\times \max(400/d,1)^{1/4}/1.25$

v_c = **0.785** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **0.773** N/mm^2

$v < v_c$ no shear reinforcement required

Internal column C3

Design shear transferred to column; $V_t = Span_x \times Span_y \times N_{ult}$ = **923** kN

Design effective shear transferred to column; $V_{eff} = 1.15 \times V_t$ = **1061** kN

Area of tension steel in x-direction; $A_{sx\_ten} = A_{sxi}$ = **1570** mm^2/m

Area of tension steel in y-direction; $A_{sy\_ten} = A_{syi}$ = **1570** mm^2/m

Column perimeter; $u_c = 2 \times (l_x + l_y)$ = **1600** mm

Average effective depth of reinforcement; $d = h – c - \phi_p$ = **214** mm

Maximum allowable shear stress; $v_{max} = \min(0.8 \times \sqrt{(f_{cu})}, 5)$ = **4.733** N/mm^2

Design shear stress at column perimeter; $v_0 = V_{eff} / (u_c \times d)$ = **3.099** N/mm^2

PASS - Maximum concrete shear stress not exceeded at column perimeter

Shear reinforcement at a perimeter of 1.50d - (321 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **4168** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **6544** mm^2

Design concrete shear stress;

$v_c = (\min(f_{cu},40)/25)^{1/3} \times 0.79 \times \min(100 \times A_{s\_ten}/(u \times d),3)^{1/3} \times \max(400/d,1)^{1/4}/1.25$

v_c = **0.746** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **1.190** N/mm^2

$v_c < v <= 1.6 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv})$ = **834** mm^2

Shear reinforcement at a perimeter of 2.25d - (482 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **5452** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **8560** mm^2

Design concrete shear stress;

$v_c = (\min(f_{cu},40)/25)^{1/3} \times 0.79 \times \min(100 \times A_{s\_ten}/(u \times d),3)^{1/3} \times \max(400/d,1)^{1/4}/1.25$

v_c = **0.746** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **0.910** N/mm^2

$v_c < v <= 1.6 \times v_c$

Shear reinforcement required at perimeter; $A_{sv\_req} = (v - v_c) \times u \times d / (0.95 \times f_{yv})$ = **403** mm^2

Shear reinforcement at a perimeter of 3.00d - (642 mm)

Length of shear perimeter; $u = u_c + (2 \times (k_x \times k_y) \times k \times d)$ = **6736** mm

Area of tension steel at shear perimeter; $A_{s\_ten} = (k_y \times (p_x + (k_x \times k \times d)) \times A_{sy\_ten}) + (k_x \times (p_y + (k_y \times k \times d)) \times A_{sx\_ten})$

A_{s_ten} = **10576** mm^2

Design concrete shear stress;

$v_c = (\min(f_{cu},40)/25)^{1/3} \times 0.79 \times \min(100 \times A_{s\_ten}/(u \times d),3)^{1/3} \times \max(400/d,1)^{1/4}/1.25$

v_c = **0.746** N/mm^2

Nominal design shear stress at perimeter; $v = V_{eff} / (u \times d)$ = **0.736** N/mm^2

$v < v_c$ no shear reinforcement required

CURTAILMENT OF REINFORCEMENT

Internal column

Radius of circular yield line; $r = (l_x \times l_y / \pi)^{1/2} \times (1.05 \times Span_x \times 1.05 \times Span_y / (l_x \times l_y))^{1/3}$ = **1601** mm

Minimum curtailment length in x-direction; $l_{int\_x} = Max(r + 12 \times D, 0.25 \times Span_x)$ = **1841** mm

Minimum curtailment length in y-direction; $l_{int\_y} = Max(r + 12 \times D, 0.25 \times Span_y)$ = **1841** mm

Corner column

Radius of yield line; $r = (l_{x1} \times l_y / \pi)^{1/2} \times ((0.45 \times Span_x + e_x) \times (0.45 \times Span_y + e_y)/ (l_{x1} \times l_y))^{1/3}$

r = **863** mm

Minimum curtailment length in x-direction; $l_{corner\_x} = Max(r + 12 \times D, 0.2 \times Span_x)$ = **1440** mm

Minimum curtailment length in y-direction; l_{corner_y} = Max(r + 12 × D, 0.2 × $Span_y$) = **1440** mm

Edge columns

Radius of yield line in x-direction; $r = (l_{x1} \times l_y / \pi)^{1/2} \times ((0.45 \times Span_x + e_x) \times (1.05 \times Span_y) / (l_{x1} \times l_y))^{1/3}$

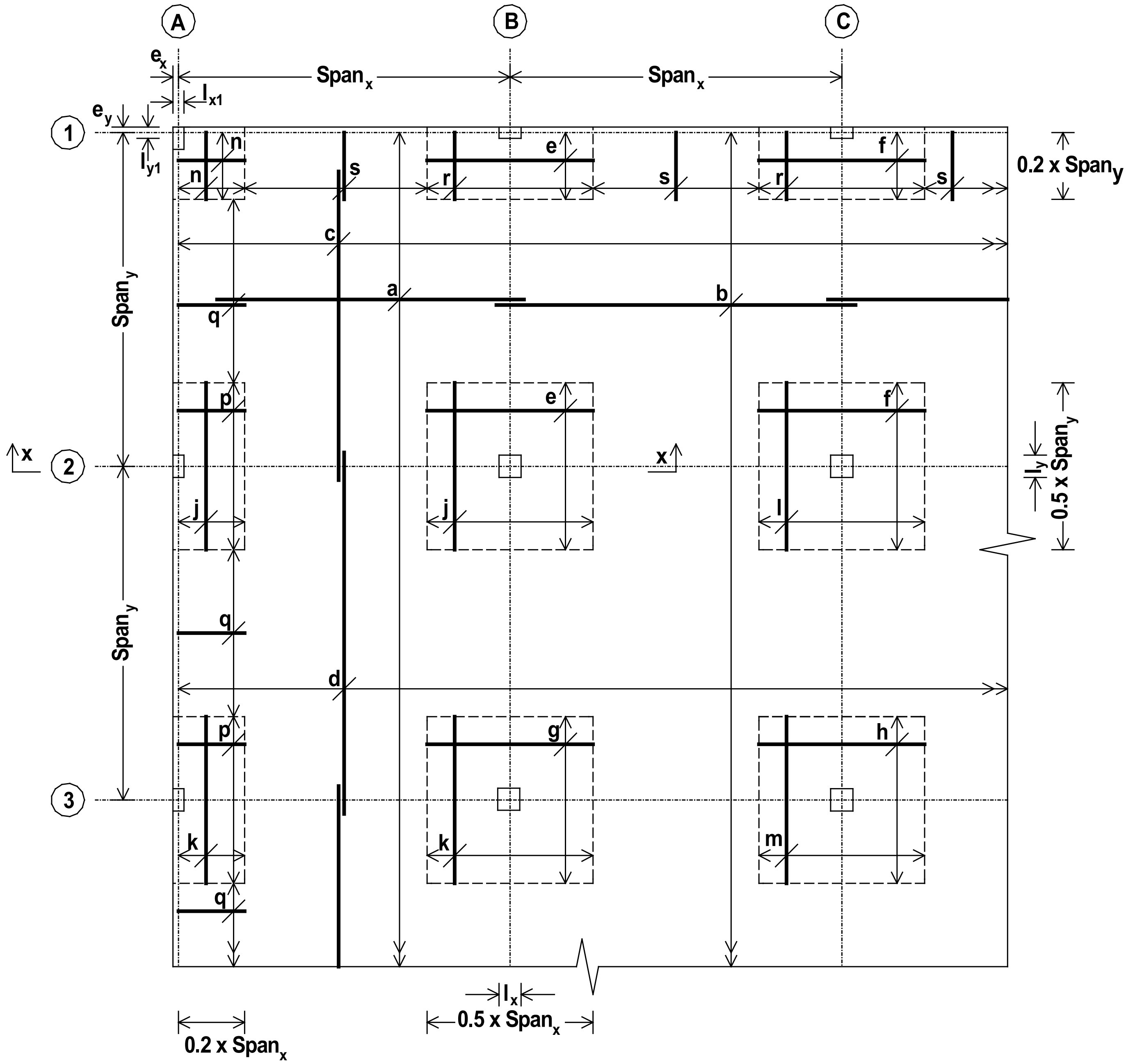
r = **1130** mm

Minimum curtailment length in x-direction; l_{edge_x} = Max(r + 12 × D, 0.2 × $Span_x$) = **1440** mm

Radius of yield line in y-direction; $r = (l_x \times l_{y1} / \pi)^{1/2} \times ((0.45 \times Span_y + e_y) \times (1.05 \times Span_x) / (l_x \times l_{y1}))^{1/3}$

r = **1130** mm

Minimum curtailment length in y-direction; l_{edge_y} = Max(r + 12 × D, 0.2 × $Span_y$) = **1440** mm



When the effective span in the x direction, L_x, is greater than the effective span in the y direction, L_y, the reinforcement in the outer layer is assumed to be that in the x direction otherwise it is assumed to be that in the y direction.

REINFORCEMENT KEY

a = 20 dia bars @ 150 centres - (2094 mm^2/m);
b = 16 dia bars @ 200 centres - (1005 mm^2/m)
c = 20 dia bars @ 200 centres - (1570 mm^2/m);
d = 16 dia bars @ 200 centres - (1005 mm^2/m)
e = 20 dia bars @ 125 centres - (2513 mm^2/m);
f = 20 dia bars @ 200 centres - (1570 mm^2/m)
g = 20 dia bars @ 150 centres - (2094 mm^2/m);
h = 20 dia bars @ 200 centres - (1570 mm^2/m)
j = 20 dia bars @ 150 centres - (2094 mm^2/m);
k = 20 dia bars @ 200 centres - (1570 mm^2/m)
l = 20 dia bars @ 150 centres - (2094 mm^2/m);
m = 20 dia bars @ 200 centres - (1570 mm^2/m)
n = 16 dia bars @ 150 centres - (1340 mm^2/m)
p = 16 dia bars @ 175 centres - (1148 mm^2/m);
q = 16 dia bars @ 150 centres - (1340 mm^2/m)
r = 16 dia bars @ 175 centres - (1148 mm^2/m);
s = 16 dia bars @ 200 centres - (1005 mm^2/m)

Distribution bars = 12 dia bars @ 300 centres - (377 mm^2/m)

Shear reinforcement is required - Refer to output above for details.