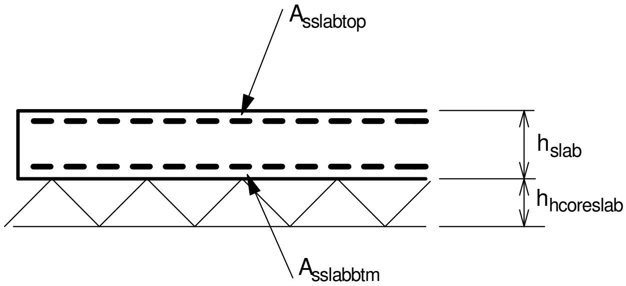
RAFT FOUNDATION DESIGN (BS8110 : PART 1 : 1997)

Tedds calculation version 1.0.12



Soil and raft definition

Soil definition

Allowable bearing pressure	q_{allow} = **50.0** kN/m^2
Number of types of soil forming sub-soil	**One type only**
Soil density	**Firm to loose**
Depth of hardcore beneath slab	$h_{hcoreslab}$ = **150** mm (Dispersal allowed for bearing pressure check)
Density of hardcore	γ_{hcore} = **20.0** kN/m^3
Basic assumed diameter of local depression	$\phi_{depbasic}$ = **2000**mm
Diameter under slab modified for hardcore	$\phi_{depslab} = \phi_{depbasic} - h_{hcoreslab}$ = **1850** mm

Raft slab definition

Max dimension/max dimension between joints	l_{max} = **20.000** m
Slab thickness	h_{slab} = **250** mm
Concrete strength	f_{cu} = **40** N/mm^2
Poissons ratio of concrete	ν = **0.2**
Slab mesh reinforcement strength	f_{yslab} = **500** N/mm^2
Partial safety factor for steel reinforcement	γ_s = **1.15**
From C&CA document ‘Concrete ground floors’ Table 5	
Minimum mesh required in top for shrinkage	**A252**
Actual mesh provided in top	**A393 ($A_{sslabtop}$ = 393 mm^2/m)**
Mesh provided in bottom	**A393 ($A_{sslabbtm}$ = 393 mm^2/m)**
Top mesh bar diameter	$\phi_{slabtop}$ = **10** mm
Bottom mesh bar diameter	$\phi_{slabbtm}$ = **10** mm
Cover to top reinforcement	c_{top} = **20** mm
Cover to bottom reinforcement	c_{btm} = **40** mm
Average effective depth of top reinforcement	$d_{tslabav} = h_{slab} - c_{top} - \phi_{slabtop}$ = **220** mm
Average effective depth of bottom reinforcement	$d_{bslabav} = h_{slab} - c_{btm} - \phi_{slabbtm}$ = **200** mm
Overall average effective depth	$d_{slabav} = (d_{tslabav} + d_{bslabav})/2$ = **210** mm
Minimum effective depth of top reinforcement	$d_{tslabmin} = d_{tslabav} - \phi_{slabtop}/2$ = **215** mm
Minimum effective depth of bottom reinforcement	$d_{bslabmin} = d_{bslabav} - \phi_{slabbtm}/2$ = **195** mm

Slab edge reinforcement

Mesh provided in top	**A393 ($A_{sedgetop}$ = 393 mm^2/m)**
Mesh provided in bottom	**A393 ($A_{sedgebtm}$ = 393 mm^2/m)**

Internal slab design checks

Basic loading

Slab self weight $w_{slab} = 24 \text{ kN/m}^3 \times h_{slab} = \mathbf{6.0} \text{ kN/m}^2$

Hardcore $w_{hcoreslab} = \gamma_{hcore} \times h_{hcoreslab} = \mathbf{3.0} \text{ kN/m}^2$

Applied loading

Uniformly distributed dead load $w_{Dudl} = \mathbf{0.0} \text{ kN/m}^2$

Uniformly distributed live load $w_{Ludl} = \mathbf{5.0} \text{ kN/m}^2$

Internal slab bearing pressure check

Total uniform load at formation level $w_{udl} = w_{slab} + w_{hcoreslab} + w_{Dudl} + w_{Ludl} = \mathbf{14.0} \text{ kN/m}^2$

PASS - w_{udl} <= q_{allow} - Applied bearing pressure is less than allowable

Internal slab bending and shear check

Applied bending moments

Span of slab $l_{slab} = \phi_{depslab} + d_{tslabav} = \mathbf{2070} \text{ mm}$

Ultimate self weight udl $w_{swult} = 1.4 \times w_{slab} = \mathbf{8.4} \text{ kN/m}^2$

Self weight moment at centre $M_{csw} = w_{swult} \times l_{slab}^2 \times (1 + \nu) / 64 = \mathbf{0.7} \text{ kNm/m}$

Self weight moment at edge $M_{esw} = w_{swult} \times l_{slab}^2 / 32 = \mathbf{1.1} \text{ kNm/m}$

Self weight shear force at edge $V_{sw} = w_{swult} \times l_{slab} / 4 = \mathbf{4.3} \text{ kN/m}$

Moments due to applied uniformly distributed loads

Ultimate applied udl $w_{udlult} = 1.4 \times w_{Dudl} + 1.6 \times w_{Ludl} = \mathbf{8.0} \text{ kN/m}^2$

Moment at centre $M_{cudl} = w_{udlult} \times l_{slab}^2 \times (1 + \nu) / 64 = \mathbf{0.6} \text{ kNm/m}$

Moment at edge $M_{eudl} = w_{udlult} \times l_{slab}^2 / 32 = \mathbf{1.1} \text{ kNm/m}$

Shear force at edge $V_{udl} = w_{udlult} \times l_{slab} / 4 = \mathbf{4.1} \text{ kN/m}$

Resultant moments and shears

Total moment at edge $M_{\Sigma e} = \mathbf{2.2} \text{ kNm/m}$

Total moment at centre $M_{\Sigma c} = \mathbf{1.3} \text{ kNm/m}$

Total shear force $V_{\Sigma} = \mathbf{8.5} \text{ kN/m}$

Reinforcement required in top

K factor $K_{slabtop} = M_{\Sigma e}/(f_{cu} \times d_{tslabav}^2) = \mathbf{0.001}$

Lever arm $z_{slabtop} = d_{tslabav} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{slabtop}/0.9)}) = \mathbf{209.0} \text{ mm}$

Area of steel required for bending $A_{sslabtopbend} = M_{\Sigma e}/((1.0/\gamma_s) \times f_{yslab} \times z_{slabtop}) = \mathbf{24} \text{ mm}^2\text{/m}$

Minimum area of steel required $A_{sslabmin} = 0.0013 \times h_{slab} = \mathbf{325} \text{ mm}^2\text{/m}$

Area of steel required $A_{sslabtopreq} = \max(A_{sslabtopbend}, A_{sslabmin}) = \mathbf{325} \text{ mm}^2\text{/m}$

PASS - $A_{sslabtopreq}$ <= $A_{sslabtop}$ - Area of reinforcement provided in top to span local depressions is adequate

Reinforcement required in bottom

K factor $K_{slabbtm} = M_{\Sigma c}/(f_{cu} \times d_{bslabav}^2) = \mathbf{0.001}$

Lever arm $z_{slabbtm} = d_{bslabav} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{slabbtm}/0.9)}) = \mathbf{190.0} \text{ mm}$

Area of steel required for bending $A_{sslabbtmbend} = M_{\Sigma c}/((1.0/\gamma_s) \times f_{yslab} \times z_{slabbtm}) = \mathbf{16} \text{ mm}^2\text{/m}$

Area of steel required $A_{sslabbtmreq} = \max(A_{sslabbtmbend}, A_{sslabmin}) = \mathbf{325} \text{ mm}^2\text{/m}$

PASS - $A_{sslabbtmreq}$ <= $A_{sslabbtm}$ - Area of reinforcement provided in bottom to span local depressions is adequate

Shear check

Applied shear stress $v = V_{\Sigma}/d_{tslabmin} = \mathbf{0.039} \text{ N/mm}^2$

Tension steel ratio $\rho = 100 \times A_{sslabtop}/d_{tslabmin} = \mathbf{0.183}$

From BS8110-1:1997 - Table 3.8

Design concrete shear strength v_c = **0.490** N/mm^2

PASS - v <= v_c - Shear capacity of the slab is adequate

Internal slab deflection check

Basic allowable span to depth ratio $Ratio_{basic}$ = **26.0**

Moment factor $M_{factor} = M_{\Sigma c}/d_{bslabav}^2$ = **0.033** N/mm^2

Steel service stress $f_s = 2/3 \times f_{yslab} \times A_{sslabbtmbend}/A_{sslabbtm}$ = **13.528** N/mm^2

Modification factor $MF_{slab} = \min(2.0, 0.55 + [(477N/mm^2 - f_s)/(120 \times (0.9N/mm^2 + M_{factor}))])$

MF_{slab} = **2.000**

Modified allowable span to depth ratio $Ratio_{allow} = Ratio_{basic} \times MF_{slab}$ = **52.000**

Actual span to depth ratio $Ratio_{actual} = l_{slab}/ d_{bslabav}$ = **10.350**

PASS - $Ratio_{actual}$ <= $Ratio_{allow}$ - Slab span to depth ratio is adequate

Slab edge design checks

Basic loading

Hardcore $w_{hcoreslab} = \gamma_{hcore} \times h_{hcoreslab}$ = **3.0** kN/m^2

Slab self weight $w_{slab} = 24\ kN/m^3 \times h_{slab}$ = **6.0** kN/m^2

Edge load number 1

Load type **Longitudinal line load**

Dead load w_{Dedge1} = **6.0** kN/m

Live load w_{Ledge1} = **0.0** kN/m

Ultimate load $w_{ultedge1} = 1.4 \times w_{Dedge1} + 1.6 \times w_{Ledge1}$ = **8.4** kN/m

Longitudinal line load width b_{edge1} = **100** mm

Centroid of load from outside face of raft x_{edge1} = **50** mm

Edge load number 2

Load type **Longitudinal line load**

Dead load w_{Dedge2} = **12.0** kN/m

Live load w_{Ledge2} = **2.0** kN/m

Ultimate load $w_{ultedge2} = 1.4 \times w_{Dedge2} + 1.6 \times w_{Ledge2}$ = **20.0** kN/m

Longitudinal line load width b_{edge2} = **100** mm

Centroid of load from outside face of raft x_{edge2} = **250** mm

Slab edge bearing pressure check

Total uniform load at formation level $w_{udledge} = w_{Dudl} + w_{Ludl} + w_{slab} + w_{hcoreslab}$ = **14.0** kN/m^2

Centroid of longitudinal and equivalent line loads from outside face of raft

Load x distance for edge load 1 $Moment_1 = w_{ultedge1} \times x_{edge1}$ = **0.4** kN

Load x distance for edge load 2 $Moment_2 = w_{ultedge2} \times x_{edge2}$ = **5.0** kN

Sum of ultimate longitud'l and equivalent line loads ΣUDL = **28.4** kN/m

Sum of load x distances $\Sigma Moment$ = **5.4** kN

Centroid of loads $x_{bar} = \Sigma Moment/\Sigma UDL$ = **191** mm

Initially assume no moment transferred into slab due to load/reaction eccentricity

Sum of unfactored longitud'l and eff'tive line loads $\Sigma UDLsls$ = **20.0** kN/m

Allowable bearing width $b_{allow} = 2 \times x_{bar} + 2 \times h_{hcoreslab} \times \tan(30)$ = **555** mm

Bearing pressure due to line/point loads $q_{linepoint} = \Sigma UDLsls/ b_{allow}$ = **36.0** kN/m^2

Total applied bearing pressure $q_{edge} = q_{linepoint} + w_{udledge}$ = **50.0** kN/m^2

q_{edge} > q_{allow} - The slab is required to resist a moment due to eccentricity

Now assume moment due to load/reaction eccentricity is resisted by slab

Bearing width required $b_{req} = \Sigma UDLsls/(q_{allow} - w_{udledge})$ = **556** mm

Effective bearing width at u/s of slab $b_{reqeff} = b_{req} - 2 \times h_{hcoreslab} \times \tan(30)$ = **382** mm

Load/reaction eccentricity $e = b_{reqeff}/2 - x_{bar}$ = **0** mm

Ultimate moment to be resisted by slab $M_{ecc} = \Sigma UDL \times e$ = **0.0** kNm/m

From slab bending check

Moment due to depression under slab (hogging) $M_{\Sigma e}$ = **2.2** kNm/m

Total moment to be resisted by slab top steel $M_{slabtop} = M_{ecc} + M_{\Sigma e}$ = **2.2** kNm/m

K factor $K_{slab} = M_{slabtop}/(f_{cu} \times d_{tslabmin}^2)$ = **0.001**

Lever arm $z_{slab} = d_{tslabmin} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{slab}/0.9)})$ = **204** mm

Area of steel required $A_{sslabreq} = M_{slabtop}/((1.0/\gamma_S) \times f_y \times z_{slab})$ = **25** mm²/m

PASS - $A_{sslabreq}$ <= $A_{sslabtop}$ - Area of reinforcement provided to transfer moment into slab is adequate

The allowable bearing pressure under the edge beam will not be exceeded

Library item - B pressure with moment transfer

Slab edge bending check

Considering a 1.0m width of slab

Divider for moments due to udl's β_{udl} = **10.0**

Applied bending moments

Span of slab $l_{edge} = \phi_{depslab} + d_{tslabmin}$ = **2065** mm

Ultimate self weight udl $w_{edgeult} = 1.4 \times w_{slab}$ = **8.4** kN/m²

Self weight bending moment $M_{edgesw} = w_{edgeult} \times l_{edge}^2/10$ = **3.6** kNm/m

Self weight shear force $V_{edgesw} = w_{edgeult} \times l_{edge}/2$ = **8.7** kN/m

Moments due to applied uniformly distributed loads

Ultimate udl $w_{edgeudl} = w_{udlult}$ = **8.0** kN/m²

Bending moment $M_{edgeudl} = w_{edgeudl} \times l_{edge}^2/\beta_{udl}$ = **3.4** kNm/m

Shear force $V_{edgeudl} = w_{edgeudl} \times l_{edge}/2$ = **8.3** kN/m

Moment and shear due to load number 1

Effective slab width $b_{eff1} = \min(x_{edge1}, b_{edge1}/2 + 0.3 \times l_{edge}) + b_{edge1}/2 + 0.3 \times l_{edge}$ = **719** mm

Bending moment $M_{edge1} = w_{ultedge1} \times l_{edge}^2/(\beta_{udl} \times b_{eff1})$ = **5.0** kNm/m

Shear force $V_{edge1} = w_{ultedge1} \times l_{edge}/(2 \times b_{eff1})$ = **12.1** kN/m

Moment and shear due to load number 2

Effective slab width $b_{eff2} = \min(x_{edge2}, b_{edge2}/2 + 0.3 \times l_{edge}) + b_{edge2}/2 + 0.3 \times l_{edge}$ = **920** mm

Bending moment $M_{edge2} = w_{ultedge2} \times l_{edge}^2/(\beta_{udl} \times b_{eff2})$ = **9.3** kNm/m

Shear force $V_{edge2} = w_{ultedge2} \times l_{edge}/(2 \times b_{eff2})$ = **22.5** kN/m

Resultant moments and shears

Total moment (hogging and sagging) $M_{\Sigma edge}$ = **21.2** kNm/m

Maximum shear force $V_{\Sigma edge}$ = **51.4** kN/m

Reinforcement required in top

K factor $K_{edgetop} = M_{\Sigma edge}/(f_{cu} \times d_{tslabmin}^2)$ = **0.011**

Lever arm $z_{edgetop} = d_{tslabmin} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{edgetop}/0.9)})$ = **204** mm

Area of steel required for bending $A_{sedgetopbend} = M_{\Sigma edge}/((1.0/\gamma_S) \times f_{yslab} \times z_{edgetop})$ = **239** mm²/m

Area of steel required $A_{sedgetopreq} = \max(A_{sedgetopbend}, A_{sslabmin})$ = **325** mm²/m

PASS - $A_{sedgetopreq}$ <= $A_{sedgetop}$ - Area of reinforcement provided in top of slab is adequate

Reinforcement required in bottom

K factor $K_{edgebtm} = M_{\Sigma edge}/(f_{cu} \times d_{bslabmin}^2)$ = **0.014**

Lever arm $z_{edgebtm} = d_{bslabmin} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{edgebtm}/0.9)})$ = **185** mm

Area of steel required for bending $A_{sedgebtmbend} = M_{\Sigma edge}/((1.0/\gamma_s) \times f_{yslab} \times z_{edgebtm}) = \mathbf{264}$ mm²/m

Area of steel required $A_{sedgebtmreq} = \max(A_{sedgebtmbend}, A_{sslabmin}) = \mathbf{325}$ mm²/m

PASS - $A_{sedgebtmreq}$ <= $A_{sedgebtm}$ - Area of reinforcement provided in bottom of slab is adequate

Applied shear stress $v_{edge} = V_{\Sigma edge} \times 1.0m/(1000mm \times d_{tslabmin}) = \mathbf{0.239}$ N/mm²

Tension steel ratio $\rho_{edge} = 100 \times A_{sedgetop} \times 1.0m/(1000mm \times d_{tslabmin}) = \mathbf{0.183}$

From BS8110-1:1997 - Table 3.8

Design concrete shear strength $v_{cedge} = \mathbf{0.490}$ N/mm²

PASS - v_{edge} <= v_{cedge} - Shear capacity of the slab is not exceeded

Slab edge deflection check

Basic allowable span to depth ratio $Ratio_{basicedge} = \mathbf{26.0}$

Moment factor $M_{factoredge} = M_{\Sigma edge}/d_{bslabmin}^2 = \mathbf{0.559}$ N/mm²

Steel service stress $f_{sedge} = 2/3 \times f_{yslab} \times A_{sedgebtmbend}/A_{sedgebtm} = \mathbf{223.743}$ N/mm²

Modification factor $MF_{edge}=\min(2.0,0.55+[(477N/mm^2-f_{sedge})/(120\times(0.9N/mm^2+M_{factoredge}))])$

$MF_{edge} = \mathbf{1.997}$

Modified allowable span to depth ratio $Ratio_{allowedge} = Ratio_{basicedge} \times MF_{edge} = \mathbf{51.916}$

Actual span to depth ratio $Ratio_{actualedge} = l_{edge}/ d_{tslabmin} = \mathbf{9.605}$

PASS - $Ratio_{actualedge}$ <= $Ratio_{allowedge}$ - Slab span to depth ratio is adequate

Corner design checks

Basic loading

Corner bearing pressure check

Total uniform load at formation level $w_{udlcorner} = w_{Dudl} + w_{Ludl} + w_{slab} + w_{hcoreslab} = \mathbf{14.0}$ kN/m²

PASS - $w_{udlcorner}$ <= q_{allow} - Applied bearing pressure is less than allowable

Slab corner bending check

Cantilever span of slab at corner $l_{corner} = \phi_{depslab}/\sqrt{(2)} + d_{tslabav}/2 = \mathbf{1418}$ mm

Moment and shear due to self weight

Considering triangular loading

Maximum ultimate self weight udl $w_{swult} = 1.4 \times w_{slab} \times \phi_{depslab}/\sqrt{(2)} = \mathbf{11.0}$ kN/m

Self weight bending moment $M_{cornersw} = w_{swult} \times l_{corner}^2/(6 \times \phi_{depslab}/\sqrt{(2)}) = \mathbf{2.8}$ kNm/m

Self weight shear force $V_{cornersw} = w_{swult} \times l_{corner}/(2 \times \phi_{depslab}/\sqrt{(2)}) = \mathbf{6.0}$ kN/m

Moment and shear due to udls

Maximum ultimate udl $w_{cornerudl} = ((1.4\times w_{Dudl})+(1.6\times w_{Ludl})) \times \phi_{depslab}/\sqrt{(2)} = \mathbf{10.5}$ kN/m

Bending moment $M_{cornerudl} = w_{cornerudl} \times l_{corner}^2/(6 \times \phi_{depslab}/\sqrt{(2)}) = \mathbf{2.7}$ kNm/m

Shear force $V_{cornerudl} = w_{cornerudl} \times l_{corner}/(2 \times \phi_{depslab}/\sqrt{(2)}) = \mathbf{5.7}$ kN/m

Resultant moments and shears

Total design moment $M_{\Sigma corner} = M_{cornersw}+ M_{cornerudl} = \mathbf{5.5}$ kNm/m

Total design shear force $V_{\Sigma corner} = V_{cornersw}+ V_{cornerudl} = \mathbf{11.6}$ kN/m

Reinforcement required in top of slab at corners

K factor $K_{corner} = M_{\Sigma corner}/(f_{cu} \times d_{tslabmin}^2) = \mathbf{0.003}$

Lever arm $z_{corner} = d_{tslabmin} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{corner}/0.9)}) = \mathbf{204}$ mm

Area of steel required for bending $A_{scornerbend} = M_{\Sigma corner}/((1.0/\gamma_s) \times f_{yslab} \times z_{corner}) = \mathbf{62}$ mm²/m

Area of steel required $A_{scorner} = \max(A_{scornerbend}, A_{sslabmin}) = \mathbf{325}$ mm²/m

PASS - $A_{scorner}$ <= $A_{sedgetop}$ - Area of reinforcement provided in top of slab at corners is adequate

Applied shear stress $v_{corner} = V_{\Sigma corner}/d_{tslabmin} = \mathbf{0.054}$ N/mm²

Tension steel ratio $\rho_{corner} = 100 \times A_{sedgetop}/d_{tslabmin} = \mathbf{0.183}$

From BS8110-1:1997 - Table 3.8

Design concrete shear strength $v_{ccorner}$ = **0.490** N/mm^2

Pass - v_{corner} <= $v_{ccorner}$ - Shear capacity of the slab is not exceeded

Slab corner deflection check

Basic allowable span to depth ratio $Ratio_{basiccorner}$ = **7.0**

Moment factor $M_{factorcorner} = M_{\Sigma corner}/d_{tslabmin}^2$ = **0.119** N/mm^2

Steel service stress $f_{scorner} = 2/3 \times f_{yslab} \times A_{scornerbend}/A_{sedgetop}$ = **52.503** N/mm^2

Modification factor $MF_{corner}=\min(2.0,0.55+[(477N/mm^2-f_{scorner})/(120\times(0.9N/mm^2+M_{factorcorner}))])$

MF_{corner} = **2.000**

Modified allowable span to depth ratio $Ratio_{allowcorner} = Ratio_{basiccorner} \times MF_{corner}$ = **14.000**

Actual span to depth ratio $Ratio_{actualcorner} = l_{corner}/ d_{tslabmin}$ = **6.596**

PASS - $Ratio_{actualcorner}$ <= $Ratio_{allowcorner}$ - Slab span to depth ratio is adequate