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structural engineering and design

# STRUCTURAL CALCULATION PACKAGE

## SS19168
## STOWMARKET COMMUNITY CENTRE

FOR

## STOWMARKET COMMUNITY CENTRE

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ALL DIMENSIONS ARE FOR OUR DESIGN PURPOSES ONLY

CALCULATIONS TO BE READ IN CONJUNCTION WITH LATEST DRAWINGS AND DETAILS

INFORMATION RELATING TO RISKS TO HEALTH AND SAFETY IS INCLUDED IN OTHER DOCUMENTATION

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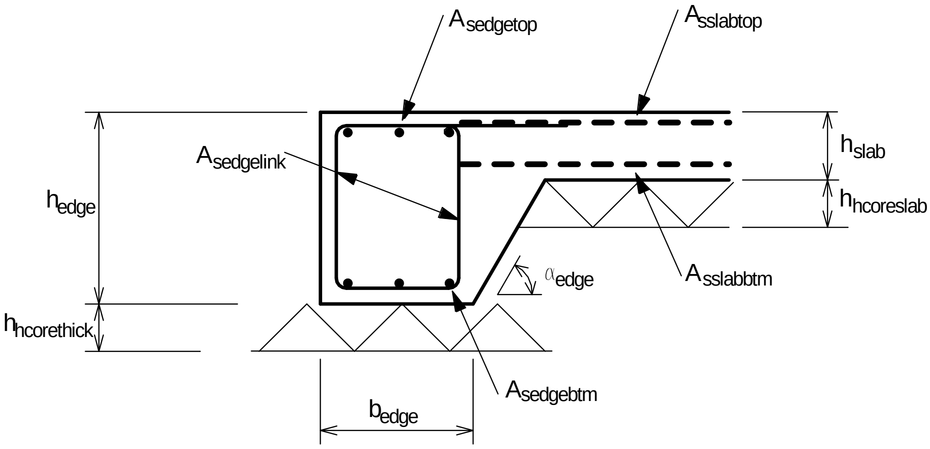
# RAFT FOUNDATION

# RC RAFT FOUNDATION (BS8110)

## 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 **Two or more types**

Soil density **Firm to loose**

Depth of hardcore beneath slab $h_{hcoreslab}$ = **150** mm (Dispersal allowed for bearing pressure check)

Depth of hardcore beneath thickenings $h_{hcorethick}$ = **150** mm (Dispersal allowed for bearing pressure check)

Density of hardcore $\gamma_{hcore}$ = **20.0** kN/m$^3$

Basic assumed diameter of local depression $\phi_{depbasic}$ = **3500**mm

Diameter under slab modified for hardcore $\phi_{depslab} = \phi_{depbasic} - h_{hcoreslab}$ = **3350** mm

Diameter under thickenings modified for hardcore $\phi_{depthick} = \phi_{depbasic} - h_{hcorethick}$ = **3350** mm

**Raft slab definition**

Max dimension/max dimension between joints $l_{max}$ = **20.000** m

Slab thickness $h_{slab}$ = **200** mm

Concrete strength $f_{cu}$ = **30** N/mm$^2$

Poissons ratio of concrete $\nu$ = **0.2**

Slab mesh reinforcement strength $f_{yslab}$ = **500** N/mm$^2$

Partial safety factor for steel reinforcement $\gamma_s$ = **1.15**

From C&CA document ‘Concrete ground floors’ Table 5

Minimum mesh required in top for shrinkage **A193**

Actual mesh provided in top **A393 ($A_{sslabtop}$ = 393 mm$^2$/m)**

Mesh provided in bottom **A393 ($A_{sslabbtm}$ = 393 mm²/m)**

Top mesh bar diameter $\phi_{slabtop}$ = **10** mm

Bottom mesh bar diameter $\phi_{slabbtm}$ = **10** mm

Cover to top reinforcement $c_{top}$ = **30** mm

Cover to bottom reinforcement $c_{btm}$ = **30** mm

Average effective depth of top reinforcement $d_{tslabav} = h_{slab} - c_{top} - \phi_{slabtop}$ = **160** mm

Average effective depth of bottom reinforcement $d_{bslabav} = h_{slab} - c_{btm} - \phi_{slabbtm}$ = **160** mm

Overall average effective depth $d_{slabav} = (d_{tslabav} + d_{bslabav})/2$ = **160** mm

Minimum effective depth of top reinforcement $d_{tslabmin} = d_{tslabav} - \phi_{slabtop}/2$ = **155** mm

Minimum effective depth of bottom reinforcement $d_{bslabmin} = d_{bslabav} - \phi_{slabbtm}/2$ = **155** mm

**Edge beam definition**

Overall depth $h_{edge}$ = **450** mm

Width $b_{edge}$ = **300** mm

Angle of chamfer to horizontal $\alpha_{edge}$ = **60** deg

Strength of main bar reinforcement $f_y$ = **500** N/mm²

Strength of link reinforcement $f_{ys}$ = **500** N/mm²

Reinforcement provided in top **2 H16 bars ($A_{sedgetop}$ = 402 mm²)**

Reinforcement provided in bottom **2 H16 bars ($A_{sedgebtm}$ = 402 mm²)**

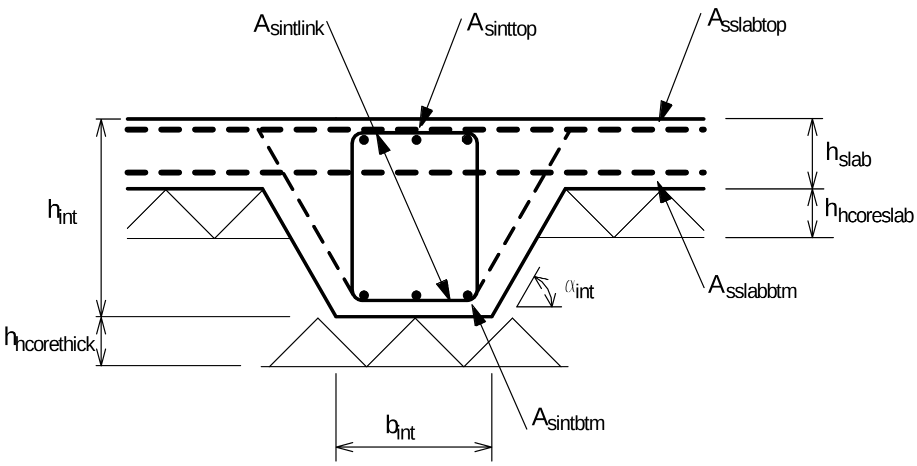
Link reinforcement provided **2 H10 legs at 200 ctrs ($A_{sv}/s_v$ = 0.785 mm)**

Bottom cover to links $c_{beam}$ = **30** mm

Effective depth of top reinforcement $d_{edgetop} = h_{edge} - c_{top} - \phi_{slabtop} - \phi_{edgelink} - \phi_{edgetop}/2$ = **392** mm

Effective depth of bottom reinforcement $d_{edgebtm} = h_{edge} - c_{beam} - \phi_{edgelink} - \phi_{edgebtm}/2$ = **402** mm

**Internal beam definition**




Overall depth $h_{int}$ = **450** mm

Width $b_{int}$ = **300** mm

Angle of chamfer to horizontal $\alpha_{int}$ = **60** deg

| | |
|---|---|
| Strength of main bar reinforcement | $f_y$ = **500** N/mm$^2$ |
| Strength of link reinforcement | $f_{ys}$ = **500** N/mm$^2$ |
| Reinforcement provided in top | **2 H16 bars ($A_{sinttop}$ = 402 mm$^2$)** |
| Reinforcement provided in bottom | **2 H16 bars ($A_{sintbtm}$ = 402 mm$^2$)** |
| Link reinforcement provided | **2 H10 legs at 200 ctrs ($A_{sv}/s_v$ = 0.785 mm)** |
| Effective depth of top reinforcement | $d_{inttop} = h_{int} - c_{top} - 2 \times \phi_{slabtop} - \phi_{inttop}/2$ = **392** mm |
| Effective depth of bottom reinforcement | $d_{intbtm} = h_{int} - c_{beam} - \phi_{intlink} - \phi_{intbtm}/2$ = **402** mm |

## Internal slab design checks

### Basic loading

| | |
|---|---|
| Slab self weight | $w_{slab} = 24 \text{ kN/m}^3 \times h_{slab}$ = **4.8** kN/m$^2$ |
| Hardcore | $w_{hcoreslab} = \gamma_{hcore} \times h_{hcoreslab}$ = **3.0** kN/m$^2$ |

### Applied loading

| | |
|---|---|
| Uniformly distributed dead load | $w_{Dudl}$ = **2.5** kN/m$^2$ |
| Uniformly distributed live load | $w_{Ludl}$ = **1.5** kN/m$^2$ |

### Internal slab bearing pressure check

| | |
|---|---|
| Total uniform load at formation level | $w_{udl} = w_{slab} + w_{hcoreslab} + w_{Dudl} + w_{Ludl}$ = **11.8** 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 | $l_{slab} = \phi_{depslab} + d_{tslabav}$ = **3510** mm |
| Ultimate self weight udl | $w_{swult} = 1.4 \times w_{slab}$ = **6.7** kN/m$^2$ |
| Self weight moment at centre | $M_{csw} = w_{swult} \times l_{slab}^2 \times (1 + \nu) / 64$ = **1.6** kNm/m |
| Self weight moment at edge | $M_{esw} = w_{swult} \times l_{slab}^2 / 32$ = **2.6** kNm/m |
| Self weight shear force at edge | $V_{sw} = w_{swult} \times l_{slab} / 4$ = **5.9** kN/m |

### Moments due to applied uniformly distributed loads

| | |
|---|---|
| Ultimate applied udl | $w_{udlult} = 1.4 \times w_{Dudl} + 1.6 \times w_{Ludl}$ = **5.9** kN/m$^2$ |
| Moment at centre | $M_{cudl} = w_{udlult} \times l_{slab}^2 \times (1 + \nu) / 64$ = **1.4** kNm/m |
| Moment at edge | $M_{eudl} = w_{udlult} \times l_{slab}^2 / 32$ = **2.3** kNm/m |
| Shear force at edge | $V_{udl} = w_{udlult} \times l_{slab} / 4$ = **5.2** kN/m |

### Resultant moments and shears

| | |
|---|---|
| Total moment at edge | $M_{\Sigma e}$ = **4.9** kNm/m |
| Total moment at centre | $M_{\Sigma c}$ = **2.9** kNm/m |
| Total shear force | $V_{\Sigma}$ = **11.1** kN/m |

### Reinforcement required in top

| | |
|---|---|
| K factor | $K_{slabtop} = M_{\Sigma e}/(f_{cu} \times d_{tslabav}^2)$ = **0.006** |
| Lever arm | $z_{slabtop} = d_{tslabav} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{slabtop}/0.9)})$ = **152.0** |
| mm | |
| Area of steel required for bending | $A_{sslabtopbend} = M_{\Sigma e}/((1.0/\gamma_s) \times f_{yslab} \times z_{slabtop})$ = **74** mm$^2$/m |
| Minimum area of steel required | $A_{sslabmin} = 0.0013 \times h_{slab}$ = **260** mm$^2$/m |



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Area of steel required $A_{sslabtopreq} = max(A_{sslabtopbend}, A_{sslabmin})$ = **260** mm$^2$/m

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

**Reinforcement required in bottom**

K factor $K_{slabbtm} = M_{\Sigma c}/(f_{cu} \times d_{bslabav}^2)$ = **0.004**

Lever arm $z_{slabbtm} = d_{bslabav} \times min(0.95, 0.5 + \sqrt{(0.25 - K_{slabbtm}/0.9)})$ = **152.0**
mm

Area of steel required for bending $A_{sslabbtmbend} = M_{\Sigma c}/((1.0/\gamma_S) \times f_{yslab} \times z_{slabbtm})$ = **44** mm$^2$/m

Area of steel required $A_{sslabbtmreq} = max(A_{sslabbtmbend}, A_{sslabmin})$ = **260** mm$^2$/m

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

**Shear check**

Applied shear stress $v = V_{\Sigma}/d_{tslabmin}$ = **0.071** N/mm$^2$

Tension steel ratio $\rho = 100 \times A_{sslabtop}/d_{tslabmin}$ = **0.254**

From BS8110-1:1997 - Table 3.8

Design concrete shear strength $v_c$ = **0.539** 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 $M_{factor} = M_{\Sigma c}/d_{bslabav}^2$ = **0.114** N/mm$^2$

Steel service stress $f_s = 2/3 \times f_{yslab} \times A_{sslabbtmbend}/A_{sslabbtm}$ = **37.415** 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 $Ratio_{actual} = l_{slab}/ d_{bslabav}$ = **21.938**

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

**<u>Edge beam design checks</u>**

**Basic loading**

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

Edge beam

Rectangular beam element $w_{beam} = 24 kN/m^3 \times h_{edge} \times b_{edge}$ = **3.2** kN/m

Chamfer element $w_{chamfer} = 24 kN/m^3 \times (h_{edge} - h_{slab})^2/(2 \times tan(\alpha_{edge}))$ = **0.4** kN/m

Slab element $w_{slabelmt} = 24 kN/m^3 \times h_{slab} \times (h_{edge} - h_{slab})/tan(\alpha_{edge})$ = **0.7** kN/m

Edge beam self weight $w_{edge} = w_{beam} + w_{chamfer} + w_{slabelmt}$ = **4.4** kN/m

**Edge load number 1**

Load type **Longitudinal line load**

Dead load $w_{Dedge1}$ = **0.8** kN/m

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

Ultimate load $w_{ultedge1} = 1.4 \times w_{Dedge1} + 1.6 \times w_{Ledge1}$ = **1.1** kN/m

Longitudinal line load width $b_{edge1}$ = **215** mm

Centroid of load from outside face of raft $x_{edge1}$ = **0** mm

**Edge load number 2**



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Load type | **Longitudinal line load**

Dead load $w_{Dedge2}$ = **5.2** kN/m

Live load $w_{Ledge2}$ = **0.0** kN/m

Ultimate load $w_{ultedge2} = 1.4 \times w_{Dedge2} + 1.6 \times w_{Ledge2}$ = **7.2** kN/m

Longitudinal line load width $b_{edge2}$ = **215** mm

Centroid of load from outside face of raft $x_{edge2}$ = **100** mm

**Edge beam bearing pressure check**

Effective bearing width of edge beam $b_{bearing} = b_{edge} + (h_{edge} - h_{slab})/\tan(\alpha_{edge})$ = **444** mm

Total uniform load at formation level $w_{udledge} = w_{Dudl}+w_{Ludl}+w_{edge}/b_{bearing}+w_{hcorethick}$ = **16.8** kN/m$^2$

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

Load x distance for edge load 1 $Moment_1 = w_{ultedge1} \times x_{edge1}$ = **0.0** kN

Load x distance for edge load 2 $Moment_2 = w_{ultedge2} \times x_{edge2}$ = **0.7** kN

Sum of ultimate longitud'l and equivalent line loads $\Sigma UDL$ = **8.3** kN/m

Sum of load x distances $\Sigma Moment$ = **0.7** kN

Centroid of loads $x_{bar} = \Sigma Moment/\Sigma UDL$ = **87** mm

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

Sum of unfactored longitud'l and eff'tive line loads $\Sigma UDLsls$ = **5.9** kN/m

Allowable bearing width $b_{allow} = 2 \times x_{bar} + 2 \times h_{hcoreslab} \times \tan(30)$ = **347** mm

Bearing pressure due to line/point loads $q_{linepoint} = \Sigma UDLsls/ b_{allow}$ = **17.1** kN/m$^2$

Total applied bearing pressure $q_{edge} = q_{linepoint} + w_{udledge}$ = **33.9** kN/m$^2$

***PASS - $q_{edge}$ <= $q_{allow}$ - Allowable bearing pressure is not exceeded***

**Edge beam bending check**

Divider for moments due to udl's $\beta_{udl}$ = **10.0**

**Applied bending moments**

Span of edge beam $l_{edge} = \phi_{depthick} + d_{edgetop}$ = **3742** mm

Ultimate self weight udl $w_{edgeult} = 1.4 \times w_{edge}$ = **6.1** kN/m

Ultimate slab udl (approx) $w_{edgeslab} = \max(0 \text{ kN/m},1.4\times w_{slab}\times((\phi_{depthick}/2\times 3/4)-(b_{edge}+(h_{edge}-h_{slab})/\tan(\alpha_{edge}))))$

$w_{edgeslab}$ = **5.5** kN/m

Self weight and slab bending moment $M_{edgesw} = (w_{edgeult} + w_{edgeslab}) \times l_{edge}^2/\beta_{udl}$ = **16.2** kNm

Self weight shear force $V_{edgesw} = (w_{edgeult} + w_{edgeslab}) \times l_{edge}/2$ = **21.6** kN

**Moments due to applied uniformly distributed loads**

Ultimate udl (approx) $w_{edgeudl} = w_{udlult} \times \phi_{depthick}/2 \times 3/4$ = **7.4** kN/m

Bending moment $M_{edgeudl} = w_{edgeudl} \times l_{edge}^2/\beta_{udl}$ = **10.4** kNm

Shear force $V_{edgeudl} = w_{edgeudl} \times l_{edge}/2$ = **13.9** kN

**Moment and shear due to load number 1**

Bending moment $M_{edge1} = w_{ultedge1} \times l_{edge}^2/\beta_{udl}$ = **1.5** kNm

Shear force $V_{edge1} = w_{ultedge1} \times l_{edge}/2$ = **2.0** kN

**Moment and shear due to load number 2**

Bending moment $M_{edge2} = w_{ultedge2} \times l_{edge}^2/\beta_{udl}$ = **10.1** kNm

Shear force — $V_{edge2} = w_{ultedge2} \times l_{edge}/2 =$ **13.5** kN

### Resultant moments and shears

Total moment (hogging and sagging) — $M_{\Sigma edge} =$ **38.2** kNm

Maximum shear force — $V_{\Sigma edge} =$ **51.0** kN

### Reinforcement required in top

Width of section in compression zone — $b_{edgetop} = b_{edge} =$ **300** mm

Average web width — $b_w = b_{edge} + (h_{edge}/\tan(\alpha_{edge}))/2 =$ **430** mm

K factor — $K_{edgetop} = M_{\Sigma edge}/(f_{cu} \times b_{edgetop} \times d_{edgetop}^2) =$ **0.028**

Lever arm — $z_{edgetop} = d_{edgetop} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{edgetop}/0.9)}) =$ **372**

mm

Area of steel required for bending — $A_{sedgetopbend} = M_{\Sigma edge}/((1.0/\gamma_s) \times f_y \times z_{edgetop}) =$ **236** mm$^2$

Minimum area of steel required — $A_{sedgetopmin} = 0.0013 \times 1.0 \times b_w \times h_{edge} =$ **251** mm$^2$

Area of steel required — $A_{sedgetopreq} = \max(A_{sedgetopbend}, A_{sedgetopmin}) =$ **251** mm$^2$

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

### Reinforcement required in bottom

Width of section in compression zone — $b_{edgebtm} = b_{edge} + (h_{edge} - h_{slab})/\tan(\alpha_{edge}) + 0.1 \times l_{edge} =$ **819** mm

K factor — $K_{edgebtm} = M_{\Sigma edge}/(f_{cu} \times b_{edgebtm} \times d_{edgebtm}^2) =$ **0.010**

Lever arm — $z_{edgebtm} = d_{edgebtm} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{edgebtm}/0.9)}) =$ **382**

mm

Area of steel required for bending — $A_{sedgebtmbend} = M_{\Sigma edge}/((1.0/\gamma_s) \times f_y \times z_{edgebtm}) =$ **230** mm$^2$

Minimum area of steel required — $A_{sedgebtmmin} = 0.0013 \times 1.0 \times b_w \times h_{edge} =$ **251** mm$^2$

Area of steel required — $A_{sedgebtmreq} = \max(A_{sedgebtmbend}, A_{sedgebtmmin}) =$ **251** mm$^2$

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

### Edge beam shear check

Applied shear stress — $v_{edge} = V_{\Sigma edge}/(b_w \times d_{edgetop}) =$ **0.303** N/mm$^2$

Tension steel ratio — $\rho_{edge} = 100 \times A_{sedgetop}/(b_w \times d_{edgetop}) =$ **0.239**

From BS8110-1:1997 - Table 3.8

Design concrete shear strength — $v_{cedge} =$ **0.419** N/mm$^2$

***$v_{edge}$ <= $v_{cedge}$ + 0.4N/mm$^2$ - Therefore minimum links required***

Link area to spacing ratio required — $A_{sv}\_upon\_s_{vreqedge} = 0.4\text{N/mm}^2 \times b_w/((1.0/\gamma_s) \times f_{ys}) =$ **0.396** mm

Link area to spacing ratio provided — $A_{sv}\_upon\_s_{vprovedge} = N_{edgelink} \times \pi \times \phi_{edgelink}^2/(4 \times s_{vedge}) =$ **0.785** mm

***PASS - $A_{sv}\_upon\_s_{vreqedge}$ <= $A_{sv}\_upon\_s_{vprovedge}$ - Shear reinforcement provided in edge beams is adequate***

## <u>Corner design checks</u>

### Basic loading

### Corner bearing pressure check

Total uniform load at formation level — $w_{udlcorner} = w_{Dudl} + w_{Ludl} + w_{edge}/b_{bearing} + w_{hcorethick} =$ **16.8** kN/m$^2$

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

### Corner beam bending check

Cantilever span of edge beam — $l_{corner} = \phi_{depthick}/\sqrt{(2)} + d_{edgetop}/2 =$ **2565** mm

**Moment and shear due to self weight**

Ultimate self weight udl $w_{edgeult} = 1.4 \times w_{edge} = \mathbf{6.1}$ kN/m

Average ultimate slab udl (approx) $w_{cornerslab} = \max(0 \text{ kN/m}, 1.4 \times w_{slab} \times (\phi_{depthick}/(\sqrt{(2)} \times 2) - (b_{edge} + (h_{edge} - h_{slab})/\tan(\alpha_{edge}))))$

$w_{cornerslab} = \mathbf{5.0}$ kN/m

Self weight and slab bending moment $M_{cornersw} = (w_{edgeult} + w_{cornerslab}) \times l_{corner}^2/2 = \mathbf{36.5}$ kNm

Self weight and slab shear force $V_{cornersw} = (w_{edgeult} + w_{cornerslab}) \times l_{corner} = \mathbf{28.4}$ kN

**Moment and shear due to udls**

Maximum ultimate udl $w_{cornerudl} = ((1.4 \times w_{Dudl}) + (1.6 \times w_{Ludl})) \times \phi_{depthick}/\sqrt{(2)} = \mathbf{14.0}$ kN/m

Bending moment $M_{cornerudl} = w_{cornerudl} \times l_{corner}^2/6 = \mathbf{15.3}$ kNm

Shear force $V_{cornerudl} = w_{cornerudl} \times l_{corner}/2 = \mathbf{17.9}$ kN

**Resultant moments and shears**

Total design moment $M_{\Sigma corner} = M_{cornersw} + M_{cornerudl} = \mathbf{51.8}$ kNm

Total design shear force $V_{\Sigma corner} = V_{cornersw} + V_{cornerudl} = \mathbf{46.4}$ kN

**Reinforcement required in top of edge beam**

K factor $K_{corner} = M_{\Sigma corner}/(f_{cu} \times b_{edgetop} \times d_{edgetop}^2) = \mathbf{0.037}$

Lever arm $z_{corner} = d_{edgetop} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{corner}/0.9)}) = \mathbf{372}$ mm

Area of steel required for bending $A_{scornerbend} = M_{\Sigma corner}/((1.0/\gamma_s) \times f_y \times z_{corner}) = \mathbf{320}$ mm$^2$

Minimum area of steel required $A_{scornermin} = A_{sedgetopmin} = \mathbf{251}$ mm$^2$

Area of steel required $A_{scorner} = \max(A_{scornerbend}, A_{scornermin}) = \mathbf{320}$ mm$^2$

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

**Corner beam shear check**

Average web width $b_w = b_{edge} + (h_{edge}/\tan(\alpha_{edge}))/2 = \mathbf{430}$ mm

Applied shear stress $v_{corner} = V_{\Sigma corner}/(b_w \times d_{edgetop}) = \mathbf{0.275}$ N/mm$^2$

Tension steel ratio $\rho_{corner} = 100 \times A_{sedgetop}/(b_w \times d_{edgetop}) = \mathbf{0.239}$

From BS8110-1:1997 - Table 3.8

Design concrete shear strength $v_{ccorner} = \mathbf{0.417}$ N/mm$^2$

***$v_{corner}$ <= $v_{ccorner}$ + 0.4N/mm$^2$ - Therefore minimum links required***

Link area to spacing ratio required $A_{sv}\_upon\_s_{vreqcorner} = 0.4\text{N/mm}^2 \times b_w/((1.0/\gamma_s) \times f_{ys}) = \mathbf{0.396}$ mm

Link area to spacing ratio provided $A_{sv}\_upon\_s_{vprovedge} = N_{edgelink} \times \pi \times \phi_{edgelink}^2/(4 \times s_{vedge}) = \mathbf{0.785}$ mm

***PASS - $A_{sv}\_upon\_s_{vreqcorner}$ <= $A_{sv}\_upon\_s_{vprovedge}$ - Shear reinforcement provided in edge beams at corners is adequate***

**Corner beam deflection check**

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

Moment factor $M_{factorcorner} = M_{\Sigma corner}/(b_{edgetop} \times d_{edgetop}^2) = \mathbf{1.123}$ N/mm$^2$

Steel service stress $f_{scorner} = 2/3 \times f_y \times A_{scornerbend}/A_{sedgetop} = \mathbf{265.115}$ N/mm$^2$

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

$MF_{corner} = \mathbf{1.423}$

Modified allowable span to depth ratio $Ratio_{allowcorner} = Ratio_{basiccorner} \times MF_{corner} = \mathbf{9.959}$

Actual span to depth ratio $Ratio_{actualcorner} = l_{corner}/ d_{edgetop} = \mathbf{6.543}$



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

## Internal beam design checks

### Basic loading

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

Internal beam self weight: $w_{int}=24\ kN/m^3\times[(h_{int}\times b_{int})+(h_{int}-h_{slab})^2/\tan(\alpha_{int})+2\times h_{slab}\times(h_{int}-h_{slab})/\tan(\alpha_{int})]$

$w_{int} = \mathbf{5.5}$ kN/m

### Internal beam bearing pressure check

Total uniform load at formation level: $w_{udlint} = w_{Dudl}+w_{Ludl}+w_{hcorethick}+24kN/m^3\times h_{int} = \mathbf{17.8}$ kN/m$^2$

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

### Internal beam bending check

Divider for moments due to udl's: $\beta_{udl} = \mathbf{10.0}$

### Applied bending moments

Span of internal beam: $l_{int} = \phi_{depthick} + d_{inttop} = \mathbf{3742}$ mm

Ultimate self weight udl: $w_{intult} = 1.4 \times w_{int} = \mathbf{7.7}$ kN/m

Ultimate slab udl (approx): $w_{intslab} = \max(0\ kN/m,1.4\times w_{slab}\times((\phi_{depthick}\times3/4)-(b_{int}+2\times(h_{int}-h_{slab})/\tan(\alpha_{int}))))$

$w_{intslab} = \mathbf{12.9}$ kN/m

Self weight and slab bending moment: $M_{intsw} = (w_{intult} + w_{intslab}) \times l_{int}^2/\beta_{udl} = \mathbf{28.9}$ kNm

Self weight shear force: $V_{intsw} = (w_{intult} + w_{intslab}) \times l_{int}/2 = \mathbf{38.6}$ kN

### Moments due to applied uniformly distributed loads

Ultimate udl (approx): $w_{intudl} = w_{udlult} \times \phi_{depthick} \times 3/4 = \mathbf{14.8}$ kN/m

Bending moment: $M_{intudl} = w_{intudl} \times l_{int}^2/\beta_{udl} = \mathbf{20.8}$ kNm

Shear force: $V_{intudl} = w_{intudl} \times l_{int}/2 = \mathbf{27.7}$ kN

### Resultant moments and shears

Total moment (hogging and sagging): $M_{\Sigma int} = \mathbf{49.6}$ kNm

Maximum shear force: $V_{\Sigma int} = \mathbf{66.3}$ kN

### Reinforcement required in top

Width of section in compression zone: $b_{inttop} = b_{int} = \mathbf{300}$ mm

Average web width: $b_{wint} = b_{int} + h_{int}/\tan(\alpha_{int}) = \mathbf{560}$ mm

K factor: $K_{inttop} = M_{\Sigma int}/(f_{cu} \times b_{inttop} \times d_{inttop}^2) = \mathbf{0.036}$

Lever arm: $z_{inttop} = d_{inttop} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{inttop}/0.9)}) = \mathbf{372}$ mm

Area of steel required for bending: $A_{sinttopbend} = M_{\Sigma int}/((1.0/\gamma_s) \times f_y \times z_{inttop}) = \mathbf{306}$ mm$^2$

Minimum area of steel: $A_{sinttopmin} = 0.0013 \times b_{wint} \times h_{int} = \mathbf{327}$ mm$^2$

Area of steel required: $A_{sinttopreq} = \max(A_{sinttopbend}, A_{sinttopmin}) = \mathbf{327}$ mm$^2$

**PASS - $A_{sinttopreq}$ <= $A_{sinttop}$ - Area of reinforcement provided in top of internal beams is adequate**

### Reinforcement required in bottom

Width of section in compression zone: $b_{intbtm} = b_{int} + 2 \times (h_{int} - h_{slab})/\tan(\alpha_{int}) + 0.2 \times l_{int} = \mathbf{1337}$ mm

K factor: $K_{intbtm} = M_{\Sigma int}/(f_{cu} \times b_{intbtm} \times d_{intbtm}^2) = \mathbf{0.008}$

Lever arm $z_{intbtm} = d_{intbtm} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{intbtm}/0.9)}) = \mathbf{382}$ mm

Area of steel required for bending $A_{sintbtmbend} = M_{\Sigma int}/((1.0/\gamma_S) \times f_y \times z_{intbtm}) = \mathbf{299}$ mm$^2$

Minimum area of steel required $A_{sintbtmmin} = 0.0013 \times 1.0 \times b_{wint} \times h_{int} = \mathbf{327}$ mm$^2$

Area of steel required $A_{sintbtmreq} = \max(A_{sintbtmbend}, A_{sintbtmmin}) = \mathbf{327}$ mm$^2$

***PASS - $A_{sintbtmreq}$ <= $A_{sintbtm}$ - Area of reinforcement provided in bottom of internal beams is adequate***

**Internal beam shear check**

Applied shear stress $v_{int} = V_{\Sigma int}/(b_{wint} \times d_{inttop}) = \mathbf{0.302}$ N/mm$^2$

Tension steel ratio $\rho_{int} = 100 \times A_{sinttop}/(b_{wint} \times d_{inttop}) = \mathbf{0.183}$

From BS8110-1:1997 - Table 3.8

Design concrete shear strength $v_{cint} = \mathbf{0.381}$ N/mm$^2$

***$v_{int}$ <= $v_{cint}$ + 0.4N/mm$^2$ - Therefore minimum links required***

Link area to spacing ratio required $A_{sv}\_upon\_s_{vreqint} = 0.4\text{N/mm}^2 \times b_{wint}/((1.0/\gamma_S) \times f_{ys}) = \mathbf{0.515}$ mm

Link area to spacing ratio provided $A_{sv}\_upon\_s_{vprovint} = N_{intlink} \times \pi \times \phi_{intlink}^2/(4 \times s_{vint}) = \mathbf{0.785}$ mm

***PASS - $A_{sv}\_upon\_s_{vreqint}$ <= $A_{sv}\_upon\_s_{vprovint}$ - Shear reinforcement provided in internal beams is adequate***

# HANDRAIL BLOCKWORK WALL

# FOUNDATION ANALYSIS & DESIGN (EN1992/EN1997)

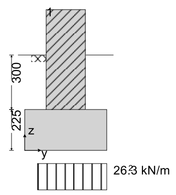
## FOUNDATION ANALYSIS (EN1997-1:2004)

**In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1**

TEDDS calculation version 3.2.19

### Strip foundation details - considering a one metre strip

Length of foundation $L_x$ = **1000** mm
Width of foundation $L_y$ = **450** mm
Foundation area $A = L_x \times L_y$ = **0.450** $m^2$
Depth of foundation h = **225** mm
Depth of soil over foundation $h_{soil}$ = **300** mm
Level of water $h_{water}$ = **0** mm
Density of water $\gamma_{water}$ = **9.8** $kN/m^3$
Density of concrete $\gamma_{conc}$ = **23.5** $kN/m^3$




### Wall no.1 details

Width of wall $l_{y1}$ = **215** mm
position in y-axis $y_1$ = **225** mm

### Soil properties

Density of soil $\gamma_{soil}$ = **18.0** $kN/m^3$
Characteristic cohesion $c'_k$ = **0** $kN/m^2$

Characteristic effective shear resistance angle $\phi'_k$ = **30** deg

Characteristic friction angle $\delta_k$ = **20** deg

**Foundation loads**

Self weight $F_{swt} = h \times \gamma_{conc}$ = **5.3** kN/m$^2$

Soil weight $F_{soil} = h_{soil} \times \gamma_{soil}$ = **5.4** kN/m$^2$

**Wall no.1 loads per linear metre**

Permanent load in z $F_{Gz1}$ = **5.2** kN

Variable load in y $F_{Qy1}$ = **1.2** kN

**Design approach 1**

**Partial factors on actions - Combination1**

Partial factor set A1

Permanent unfavourable action - Table A.3 $\gamma_G$ = **1.35**

Permanent favourable action - Table A.3 $\gamma_{Gf}$ = **1.00**

Variable unfavourable action - Table A.3 $\gamma_Q$ = **1.50**

Variable favourable action - Table A.3 $\gamma_{Qf}$ = **0.00**

**Partial factors for soil parameters - Combination1**

Soil factor set M1

Angle of shearing resistance - Table A.4 $\gamma_{\phi'}$ = **1.00**

Effective cohesion - Table A.4 $\gamma_{c'}$ = **1.00**

Weight density - Table A.4 $\gamma_\gamma$ = **1.00**

**Partial factors for spread foundations - Combination1**

Resistance factor set R1

Bearing - Table A.5 $\gamma_{R.v}$ = **1.00**

Sliding - Table A.5 $\gamma_{R.h}$ = **1.00**

**Bearing resistance (Section 6.5.2)**

**Forces on foundation per linear metre**

Force in y-axis $F_{dy} = \gamma_Q \times F_{Qy1}$ = **1.8** kN

Force in z-axis $F_{dz} = \gamma_G \times (A \times (F_{swt} + F_{soil}) + F_{Gz1})$ = **13.5** kN

**Moments on foundation per linear metre**

Moment in y-axis $M_{dy} = \gamma_G \times (A \times (F_{swt} + F_{soil}) \times L_y / 2 + F_{Gz1} \times y_1) + (\gamma_Q \times F_{Qy1}) \times h$ = **3.4** kNm

**Eccentricity of base reaction**

Eccentricity of base reaction in y-axis $e_y = M_{dy} / F_{dz} - L_y / 2$ = **30** mm

**Effective area of base per linear metre**

Effective width $L'_y = L_y - 2 \times e_y$ = **390** mm

Effective length $L'_x$ = **1000** mm

Effective area $A' = L'_x \times L'_y$ = **0.390** m$^2$

**Pad base pressure**

Design base pressure $f_{dz} = F_{dz} / A'$ = **34.5** kN/m$^2$

**Ultimate bearing capacity under drained conditions (Annex D.4)**

Design angle of shearing resistance $\phi'_d = \text{atan}(\tan(\phi'_k) / \gamma_{\phi'})$ = **30.000** deg

Design effective cohesion $c'_d = c'_k / \gamma_{c'} = \mathbf{0.000}$ kN/m$^2$

Effective overburden pressure $q = (h + h_{soil}) \times \gamma_{soil} - h_{water} \times \gamma_{water} = \mathbf{9.450}$ kN/m$^2$

Design effective overburden pressure $q' = q / \gamma_\gamma = \mathbf{9.450}$ kN/m$^2$

Bearing resistance factors $N_q = Exp(\pi \times \tan(\phi'_d)) \times (\tan(45\ deg + \phi'_d / 2))^2 = \mathbf{18.401}$

$N_c = (N_q - 1) \times \cot(\phi'_d) = \mathbf{30.140}$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_d) = \mathbf{20.093}$

Foundation shape factors $s_q = \mathbf{1.000}$

$s_\gamma = \mathbf{1.000}$

$s_c = \mathbf{1.000}$

Load inclination factors $H = abs(F_{dy}) = \mathbf{1.8}$ kN

$m_y = [2 + (L'_y / L'_x)] / [1 + (L'_y / L'_x)] = \mathbf{1.720}$

$m_x = [2 + (L'_x / L'_y)] / [1 + (L'_x / L'_y)] = \mathbf{1.280}$

$m = m_y = \mathbf{1.720}$

$i_q = [1 - H / (F_{dz} + A' \times c'_d \times \cot(\phi'_d))]^m = \mathbf{0.781}$

$i_\gamma = [1 - H / (F_{dz} + A' \times c'_d \times \cot(\phi'_d))]^{m+1} = \mathbf{0.677}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_d)) = \mathbf{0.769}$

Ultimate bearing capacity $n_f = c'_d \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{soil} \times L'_y \times N_\gamma \times s_\gamma \times i_\gamma = \mathbf{183.6}$ kN/m$^2$

***PASS - Ultimate bearing capacity exceeds design base pressure***

**Sliding resistance (Section 6.5.3)**

**Forces on foundation per linear metre**

Force in y-axis $F_{dy} = \gamma_Q \times F_{Qy1} = \mathbf{1.8}$ kN

Force in z-axis $F_{dz} = \gamma_{Gf} \times (A \times (F_{swt} + F_{soil}) + F_{Gz1}) = \mathbf{10.0}$ kN

**Sliding resistance verification per linear metre (Section 6.5.3)**

Horizontal force on foundation $H = abs(F_{dy}) = \mathbf{1.8}$ kN

Sliding resistance (exp.6.3a) $R_{H.d} = F_{dz} \times \tan(\delta_k) / \gamma_{\phi'} = \mathbf{3.6}$ kN

$H / R_{H.d} = \mathbf{0.496}$

***PASS - Foundation is not subject to failure by sliding***

Library item: Check sliding output

**Design approach 1**

**Partial factors on actions - Combination2**

Partial factor set A2

Permanent unfavourable action - Table A.3 $\gamma_G = \mathbf{1.00}$

Permanent favourable action - Table A.3 $\gamma_{Gf} = \mathbf{1.00}$

Variable unfavourable action - Table A.3 $\gamma_Q = \mathbf{1.30}$

Variable favourable action - Table A.3 $\gamma_{Qf} = \mathbf{0.00}$

**Partial factors for soil parameters - Combination2**

Soil factor set M2

Angle of shearing resistance - Table A.4 $\gamma_{\phi'} = \mathbf{1.25}$

Effective cohesion - Table A.4 $\gamma_{c'} = \mathbf{1.25}$

Weight density - Table A.4 $\gamma_\gamma = \mathbf{1.00}$

**Partial factors for spread foundations - Combination2**

Resistance factor set R1

Bearing - Table A.5 $\gamma_{R.v}$ = **1.00**

Sliding - Table A.5 $\gamma_{R.h}$ = **1.00**

**Bearing resistance (Section 6.5.2)**

**Forces on foundation per linear metre**

Force in y-axis $F_{dy} = \gamma_Q \times F_{Qy1}$ = **1.6** kN

Force in z-axis $F_{dz} = \gamma_G \times (A \times (F_{swt} + F_{soil}) + F_{Gz1})$ = **10.0** kN

**Moments on foundation per linear metre**

Moment in y-axis $M_{dy} = \gamma_G \times (A \times (F_{swt} + F_{soil}) \times L_y / 2 + F_{Gz1} \times y_1) + (\gamma_Q \times F_{Qy1}) \times h$ = **2.6** kNm

**Eccentricity of base reaction**

Eccentricity of base reaction in y-axis $e_y = M_{dy} / F_{dz} - L_y / 2$ = **35** mm

**Effective area of base per linear metre**

Effective width $L'_y = L_y - 2 \times e_y$ = **380** mm

Effective length $L'_x$ = **1000** mm

Effective area $A' = L'_x \times L'_y$ = **0.380** $m^2$

**Pad base pressure**

Design base pressure $f_{dz} = F_{dz} / A'$ = **26.3** $kN/m^2$

**Ultimate bearing capacity under drained conditions (Annex D.4)**

Design angle of shearing resistance $\phi'_d = \mathrm{atan}(\tan(\phi'_k) / \gamma_{\phi'})$ = **24.791** deg

Design effective cohesion $c'_d = c'_k / \gamma_{c'}$ = **0.000** $kN/m^2$

Effective overburden pressure $q = (h + h_{soil}) \times \gamma_{soil} - h_{water} \times \gamma_{water}$ = **9.450** $kN/m^2$

Design effective overburden pressure $q' = q / \gamma_\gamma$ = **9.450** $kN/m^2$

Bearing resistance factors $N_q = \mathrm{Exp}(\pi \times \tan(\phi'_d)) \times (\tan(45\ \mathrm{deg} + \phi'_d / 2))^2$ = **10.431**

$N_c = (N_q - 1) \times \cot(\phi'_d)$ = **20.418**

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_d)$ = **8.712**

Foundation shape factors $s_q$ = **1.000**

$s_\gamma$ = **1.000**

$s_c$ = **1.000**

Load inclination factors $H = \mathrm{abs}(F_{dy})$ = **1.6** kN

$m_y = [2 + (L'_y / L'_x)] / [1 + (L'_y / L'_x)]$ = **1.725**

$m_x = [2 + (L'_x / L'_y)] / [1 + (L'_x / L'_y)]$ = **1.275**

$m = m_y$ = **1.725**

$i_q = [1 - H / (F_{dz} + A' \times c'_d \times \cot(\phi'_d))]^m$ = **0.746**

$i_\gamma = [1 - H / (F_{dz} + A' \times c'_d \times \cot(\phi'_d))]^{m+1}$ = **0.629**

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_d))$ = **0.719**

Ultimate bearing capacity $n_f = c'_d \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_{soil} \times L'_y \times N_\gamma \times s_\gamma \times i_\gamma$ = **92.2** $kN/m^2$

***PASS - Ultimate bearing capacity exceeds design base pressure***

**Sliding resistance (Section 6.5.3)**

**Forces on foundation per linear metre**

Force in y-axis $F_{dy} = \gamma_Q \times F_{Qy1} = \mathbf{1.6}$ kN

Force in z-axis $F_{dz} = \gamma_{Gf} \times (A \times (F_{swt} + F_{soil}) + F_{Gz1}) = \mathbf{10.0}$ kN

**Sliding resistance verification per linear metre (Section 6.5.3)**

Horizontal force on foundation $H = abs(F_{dy}) = \mathbf{1.6}$ kN

Sliding resistance (exp.6.3a) $R_{H.d} = F_{dz} \times \tan(\delta_k) / \gamma_{\phi'} = \mathbf{2.9}$ kN

$H / R_{H.d} = \mathbf{0.537}$

***PASS - Foundation is not subject to failure by sliding***

Library item: Check sliding output