15658.1

STRUCTURAL CALCULATIONS FOR THE PROPOSED FIRE TANK FOUNDATIONS AT ASHWELL ENTERPRISE PARK

For Rutland CC

December 2015

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Project No: 15658	Sheet No: 1	Rev.
Made By: JGG	Checked By:	
Date: DEC 18	Date:	

Project	ASHWELL ENTERPRISE PARK
Element	WATER TANK FOUNDATIONS.

It is proposed to construct 4 No water tanks on the above site.

The water tank are 1.5m high and 6.2m in diameter.

The ground conditions are made ground on top of ground of reasonable bearing capacity. The made ground should be removed and replaced with type 1, however for the design, base the design on 'less than firm ground'.

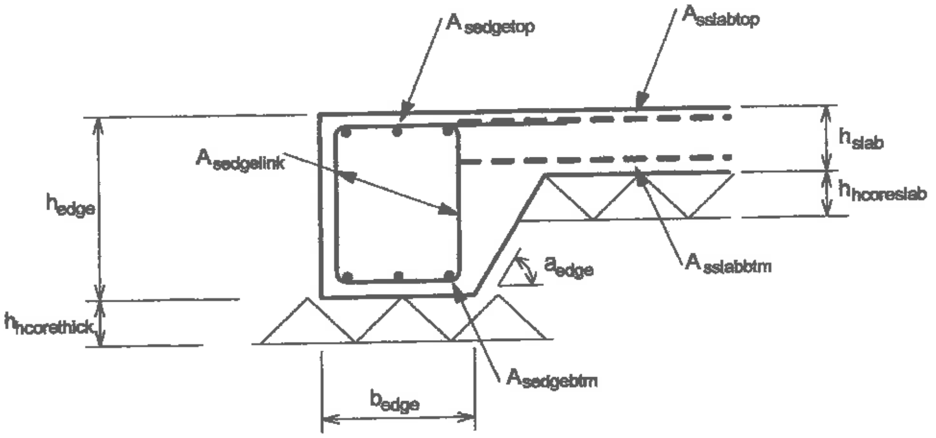
loading from water tank: Weight of water $15 kN/m^2$

Refer to sheet 2 for analysis.

JOHN GOODLIFFE ASSOCIATES PINGLE BARN, NEWSTEAD LANE BELMESTHORPE STAMFORD	Project Ashwell Enterprise Park,				Job no. 15658	
	Calcs for Water tank foundations				Start page no./Revision 2	
	Calcs by JG	Calcs date 18/12/2015	Checked by	Checked date	Approved by	Approved date

RAFT FOUNDATION DESIGN (BS8110 : PART 1 : 1997)

Tedds calculation version 1.0.11



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)
Depth of hardcore beneath thickenings	$h_{hcorethick}$ = **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**
Diameter under thickenings modified for hardcore	$\phi_{depthick} = \phi_{depbasic} - h_{hcorethick}$ = **1850** mm

Raft slab definition

Max dimension/max dimension between joints	l_{max} = **6.600** m
Slab thickness	h_{slab} = **200** mm
Concrete strength	f_{cu} = **35** 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	**A142**
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} = **35** mm
Average effective depth of top reinforcement	$d_{tslabav} = h_{slab} - c_{top} - \phi_{slabtop}$ = **170** mm
Average effective depth of bottom reinforcement	$d_{bslabav} = h_{slab} - c_{btm} - \phi_{slabbtm}$ = **155** mm
Overall average effective depth	$d_{slabav} = (d_{tslabav} + d_{bslabav})/2$ = **163** mm

Minimum effective depth of top reinforcement	$d_{tslabmin} = d_{tslabav} - \phi_{slabtop}/2$ = **165** mm
Minimum effective depth of bottom reinforcement	$d_{bslabmin} = d_{bslabav} - \phi_{slabbtm}/2$ = **150** mm

Edge beam definition

Overall depth	h_{edge} = **600** mm
Width	b_{edge} = **450** mm
Angle of chamfer to horizontal	α_{edge} = **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	**3 H16 bars ($A_{sedgetop}$ = 603 mm^2)**
Reinforcement provided in bottom	**3 H16 bars ($A_{sedgebtm}$ = 603 mm^2)**
Link reinforcement provided	**2 H10 legs at 250 ctrs (A_{sv}/s_v = 0.628 mm)**
Bottom cover to links	c_{beam} = **35** mm
Effective depth of top reinforcement	$d_{edgetop} = h_{edge} - c_{top} - \phi_{slabtop} - \phi_{edgelink} - \phi_{edgetop}/2$ = **552** mm
Effective depth of bottom reinforcement	$d_{edgebtm} = h_{edge} - c_{beam} - \phi_{edgelink} - \phi_{edgebtm}/2$ = **547** mm

Internal slab design checks

Basic loading

Slab self weight	$w_{slab} = 24\ kN/m^3 \times h_{slab}$ = **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} = **1.8** kN/m^2
Uniformly distributed live load	w_{Ludl} = **15.0** kN/m^2

Internal slab bearing pressure check

Total uniform load at formation level	$w_{udl} = w_{slab} + w_{hcoreslab} + w_{Dudl} + w_{Ludl}$ = **24.6** 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	$l_{slab} = \phi_{depslab} + d_{tslabav}$ = **2020** mm
Ultimate self weight udl	$w_{swult} = 1.4 \times w_{slab}$ = **6.7** kN/m^2
Self weight moment at centre	$M_{csw} = w_{swult} \times l_{slab}^2 \times (1 + \nu) / 64$ = **0.5** kNm/m
Self weight moment at edge	$M_{esw} = w_{swult} \times l_{slab}^2 / 32$ = **0.9** kNm/m
Self weight shear force at edge	$V_{sw} = w_{swult} \times l_{slab} / 4$ = **3.4** kN/m

Moments due to applied uniformly distributed loads

Ultimate applied udl	$w_{udlult} = 1.4 \times w_{Dudl} + 1.6 \times w_{Ludl}$ = **26.5** kN/m^2
Moment at centre	$M_{cudl} = w_{udlult} \times l_{slab}^2 \times (1 + \nu) / 64$ = **2.0** kNm/m
Moment at edge	$M_{eudl} = w_{udlult} \times l_{slab}^2 / 32$ = **3.4** kNm/m
Shear force at edge	$V_{udl} = w_{udlult} \times l_{slab} / 4$ = **13.4** kN/m

Resultant moments and shears

Total moment at edge	$M_{\Sigma e}$ = **4.2** kNm/m
Total moment at centre	$M_{\Sigma c}$ = **2.5** kNm/m
Total shear force	V_{Σ} = **16.8** kN/m

Reinforcement required in top

K factor	$K_{slabtop} = M_{\Sigma e}/(f_{cu} \times d_{tslabav}^2)$ = **0.004**
Lever arm	$z_{slabtop} = d_{tslabav} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{slabtop}/0.9)})$ = **161.5** mm
Area of steel required for bending	$A_{sslabtopbend} = M_{\Sigma e}/((1.0/\gamma_s) \times f_{yslab} \times z_{slabtop})$ = **60** mm^2/m

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Minimum area of steel required $A_{sslabmin} = 0.0013 \times h_{slab} = \mathbf{260}$ **mm²/m**

Area of steel required $A_{sslabtopreq} = \max(A_{sslabtopbend}, A_{sslabmin}) = \mathbf{260}$ **mm²/m**

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

Reinforcement required in bottom

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

Lever arm $z_{slabbtm} = d_{bslabav} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{slabbtm}/0.9)}) = \mathbf{147.3}$ **mm**

Area of steel required for bending $A_{sslabbtmbend} = M_{\Sigma c}/((1.0/\gamma_s) \times f_{yslab} \times z_{slabbtm}) = \mathbf{40}$ **mm²/m**

Area of steel required $A_{sslabbtmreq} = \max(A_{sslabbtmbend}, A_{sslabmin}) = \mathbf{260}$ **mm²/m**

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

Shear check

Applied shear stress $v = V_{\Sigma}/d_{tslabmin} = \mathbf{0.102}$ **N/mm²**

Tension steel ratio $\rho = 100 \times A_{sslabtop}/d_{tslabmin} = \mathbf{0.238}$

From BS8110-1:1997 - Table 3.8

Design concrete shear strength $v_c = \mathbf{0.547}$ **N/mm²**

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

Internal slab deflection check

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

Moment factor $M_{factor} = M_{\Sigma c}/d_{bslabav}^2 = \mathbf{0.106}$ **N/mm²**

Steel service stress $f_s = 2/3 \times f_{yslab} \times A_{sslabbtmbend}/A_{sslabbtm} = \mathbf{33.692}$ **N/mm²**

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

$MF_{slab} = \mathbf{2.000}$

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

Actual span to depth ratio $Ratio_{actual} = l_{slab}/ d_{bslabav} = \mathbf{13.032}$

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

<u>Edge beam design checks</u>

Basic loading

Hardcore $w_{hcorethick} = \gamma_{hcore} \times h_{hcorethick} = \mathbf{3.0}$ **kN/m²**

Edge beam

Rectangular beam element $w_{beam} = 24\ kN/m^3 \times h_{edge} \times b_{edge} = \mathbf{6.5}$ **kN/m**

Chamfer element $w_{chamfer} = 24\ kN/m^3 \times (h_{edge} - h_{slab})^2/(2 \times \tan(\alpha_{edge})) = \mathbf{1.1}$ **kN/m**

Slab element $w_{slabelmt} = 24\ kN/m^3 \times h_{slab} \times (h_{edge} - h_{slab})/\tan(\alpha_{edge}) = \mathbf{1.1}$ **kN/m**

Edge beam self weight $w_{edge} = w_{beam} + w_{chamfer} + w_{slabelmt} = \mathbf{8.7}$ **kN/m**

Edge beam bearing pressure check

Effective bearing width of edge beam $b_{bearing} = b_{edge} + (h_{edge} - h_{slab})/\tan(\alpha_{edge}) = \mathbf{681}$ **mm**

Total uniform load at formation level $w_{udledge} = w_{Dudl}+w_{Ludl}+w_{edge}/b_{bearing}+w_{hcorethick} = \mathbf{32.6}$ **kN/m²**

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

Edge beam bending check

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

Applied bending moments

Span of edge beam $l_{edge} = \phi_{depthick} + d_{edgetop} = \mathbf{2402}$ **mm**

Ultimate self weight udl $w_{edgeult} = 1.4 \times w_{edge} = \mathbf{12.2}$ **kN/m**

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

$w_{edgeslab} = \mathbf{0.1}$ **kN/m**

Self weight and slab bending moment $M_{edgesw} = (w_{edgeult} + w_{edgeslab}) \times l_{edge}^2/\beta_{udl} = \mathbf{7.1}$ **kNm**

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Self weight shear force $V_{edgesw} = (W_{edgeult} + W_{edgeslab}) \times l_{edge}/2 = \mathbf{14.7\ kN}$

Moments due to applied uniformly distributed loads

Ultimate udl (approx) $W_{edgeudl} = W_{udlult} \times \phi_{depthick}/2 \times 3/4 = \mathbf{18.4\ kN/m}$

Bending moment $M_{edgeudl} = W_{edgeudl} \times l_{edge}^2/\beta_{udl} = \mathbf{10.6\ kNm}$

Shear force $V_{edgeudl} = W_{edgeudl} \times l_{edge}/2 = \mathbf{22.1\ kN}$

Resultant moments and shears

Total moment (hogging and sagging) $M_{\Sigma edge} = \mathbf{17.7\ kNm}$

Maximum shear force $V_{\Sigma edge} = \mathbf{36.8\ kN}$

Reinforcement required in top

Width of section in compression zone $b_{edgetop} = b_{edge} = \mathbf{450\ mm}$

Average web width $b_w = b_{edge} + (h_{edge}/\tan(\alpha_{edge}))/2 = \mathbf{623\ mm}$

K factor $K_{edgetop} = M_{\Sigma edge}/(f_{cu} \times b_{edgetop} \times d_{edgetop}^2) = \mathbf{0.004}$

Lever arm $z_{edgetop} = d_{edgetop} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{edgetop}/0.9)}) = \mathbf{524\ mm}$

Area of steel required for bending $A_{sedgetopbend} = M_{\Sigma edge}/((1.0/\gamma_s) \times f_y \times z_{edgetop}) = \mathbf{78\ mm^2}$

Minimum area of steel required $A_{sedgetopmin} = 0.0013 \times 1.0 \times b_w \times h_{edge} = \mathbf{486\ mm^2}$

Area of steel required $A_{sedgetopreq} = \max(A_{sedgetopbend}, A_{sedgetopmin}) = \mathbf{486\ mm^2}$

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 $b_{edgebtm} = b_{edge} + (h_{edge} - h_{slab})/\tan(\alpha_{edge}) + 0.1 \times l_{edge} = \mathbf{921\ mm}$

K factor $K_{edgebtm} = M_{\Sigma edge}/(f_{cu} \times b_{edgebtm} \times d_{edgebtm}^2) = \mathbf{0.002}$

Lever arm $z_{edgebtm} = d_{edgebtm} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{edgebtm}/0.9)}) = \mathbf{520\ mm}$

Area of steel required for bending $A_{sedgebtmbend} = M_{\Sigma edge}/((1.0/\gamma_s) \times f_y \times z_{edgebtm}) = \mathbf{78\ mm^2}$

Minimum area of steel required $A_{sedgebtmmin} = 0.0013 \times 1.0 \times b_w \times h_{edge} = \mathbf{486\ mm^2}$

Area of steel required $A_{sedgebtmreq} = \max(A_{sedgebtmbend}, A_{sedgebtmmin}) = \mathbf{486\ mm^2}$

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

Edge beam shear check

Applied shear stress $v_{edge} = V_{\Sigma edge}/(b_w \times d_{edgetop}) = \mathbf{0.107\ N/mm^2}$

Tension steel ratio $\rho_{edge} = 100 \times A_{sedgetop}/(b_w \times d_{edgetop}) = \mathbf{0.175}$

From BS8110-1:1997 - Table 3.8

Design concrete shear strength $v_{cedge} = \mathbf{0.396\ N/mm^2}$

v_{edge} <= v_{cedge} + 0.4N/mm² - Therefore minimum links required

Link area to spacing ratio required $A_{sv}\_upon\_s_{vreqedge} = 0.4\text{N/mm}^2 \times b_w/((1.0/\gamma_s) \times f_{ys}) = \mathbf{0.573\ mm}$

Link area to spacing ratio provided $A_{sv}\_upon\_s_{vprovedge} = N_{edgelink} \times \pi \times \phi_{edgelink}^2/(4 \times s_{vedge}) = \mathbf{0.628\ mm}$

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

Corner design checks

Basic loading

Corner bearing pressure check

Total uniform load at formation level $w_{udlcorner} = w_{Dudl} + w_{Ludl} + W_{edge}/b_{bearing} + w_{hcorethick} = \mathbf{32.6\ kN/m^2}$

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

Corner beam bending check

Cantilever span of edge beam $l_{corner} = \phi_{depthick}/\sqrt{(2)} + d_{edgetop}/2 = \mathbf{1584\ mm}$

Moment and shear due to self weight

Ultimate self weight udl $W_{edgeult} = 1.4 \times W_{edge} = \mathbf{12.2\ kN/m}$

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

$w_{cornerslab}$ = **0.0 kN/m**

Self weight and slab bending moment — $M_{cornersw} = (w_{edgeult} + w_{cornerslab}) \times l_{corner}^2/2$ = **15.3 kNm**

Self weight and slab shear force — $V_{cornersw} = (w_{edgeult} + w_{cornerslab}) \times l_{corner}$ = **19.3 kN**

Moment and shear due to udls

Maximum ultimate udl — $w_{cornerudl} = ((1.4 \times w_{Dudl})+(1.6 \times w_{Ludl})) \times \phi_{depthick}/\sqrt{(2)}$ = **34.7 kN/m**

Bending moment — $M_{cornerudl} = w_{cornerudl} \times l_{corner}^2/6$ = **14.5 kNm**

Shear force — $V_{cornerudl} = w_{cornerudl} \times l_{corner}/2$ = **27.5 kN**

Resultant moments and shears

Total design moment — $M_{\Sigma corner} = M_{cornersw} + M_{cornerudl}$ = **29.8 kNm**

Total design shear force — $V_{\Sigma corner} = V_{cornersw} + V_{cornerudl}$ = **46.8 kN**

Reinforcement required in top of edge beam

K factor — $K_{corner} = M_{\Sigma corner}/(f_{cu} \times b_{edgetop} \times d_{edgetop}^2)$ = **0.006**

Lever arm — $z_{corner} = d_{edgetop} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{corner}/0.9)})$ = **524 mm**

Area of steel required for bending — $A_{scornerbend} = M_{\Sigma corner}/((1.0/\gamma_s) \times f_y \times z_{corner})$ = **131 mm²**

Minimum area of steel required — $A_{scornermin} = A_{sedgetopmin}$ = **486 mm²**

Area of steel required — $A_{scorner} = \max(A_{scornerbend}, A_{scornermin})$ = **486 mm²**

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 — $b_w = b_{edge} + (h_{edge}/\tan(\alpha_{edge}))/2$ = **623 mm**

Applied shear stress — $v_{corner} = V_{\Sigma corner}/(b_w \times d_{edgetop})$ = **0.136 N/mm²**

Tension steel ratio — $\rho_{corner} = 100 \times A_{sedgetop}/(b_w \times d_{edgetop})$ = **0.175**

From BS8110-1:1997 - Table 3.8

Design concrete shear strength — $v_{ccorner}$ = **0.365 N/mm²**

$v_{corner} <= v_{ccorner}$ + 0.4N/mm² - Therefore minimum links required

Link area to spacing ratio required — $A_{sv}\_upon\_s_{vreqcorner} = 0.4\text{N/mm}^2 \times b_w/((1.0/\gamma_s) \times f_{ys})$ = **0.573 mm**

Link area to spacing ratio provided — $A_{sv}\_upon\_s_{vprovedge} = N_{edgelink} \times \pi \times \phi_{edgelink}^2/(4 \times s_{vedge})$ = **0.628 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 — $Ratio_{basiccorner}$ = **7.0**

Moment factor — $M_{factorcorner} = M_{\Sigma corner}/(b_{edgetop} \times d_{edgetop}^2)$ = **0.217 N/mm²**

Steel service stress — $f_{scorner} = 2/3 \times f_y \times A_{scornerbend}/A_{sedgetop}$ = **72.199 N/mm²**

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} = **2.000**

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

Actual span to depth ratio — $Ratio_{actualcorner} = l_{corner}/ d_{edgetop}$ = **2.870**

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

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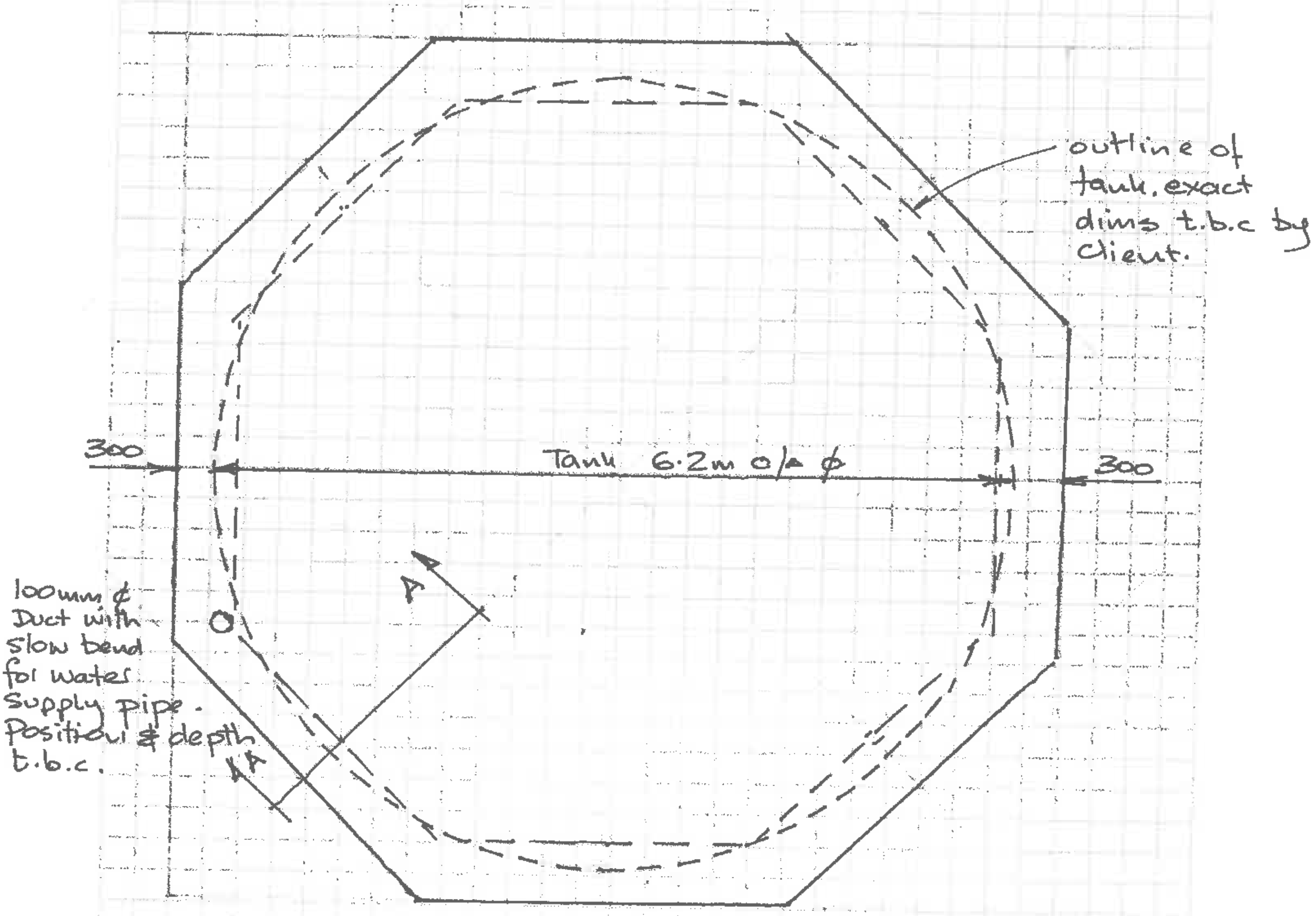
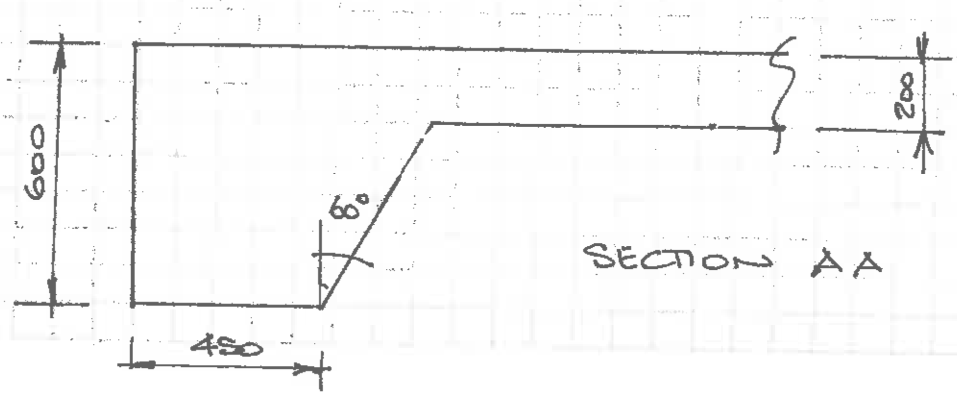
Element	FIRE TANK FOUNDATIONS



PLAN OF FOUNDATION. 1:50



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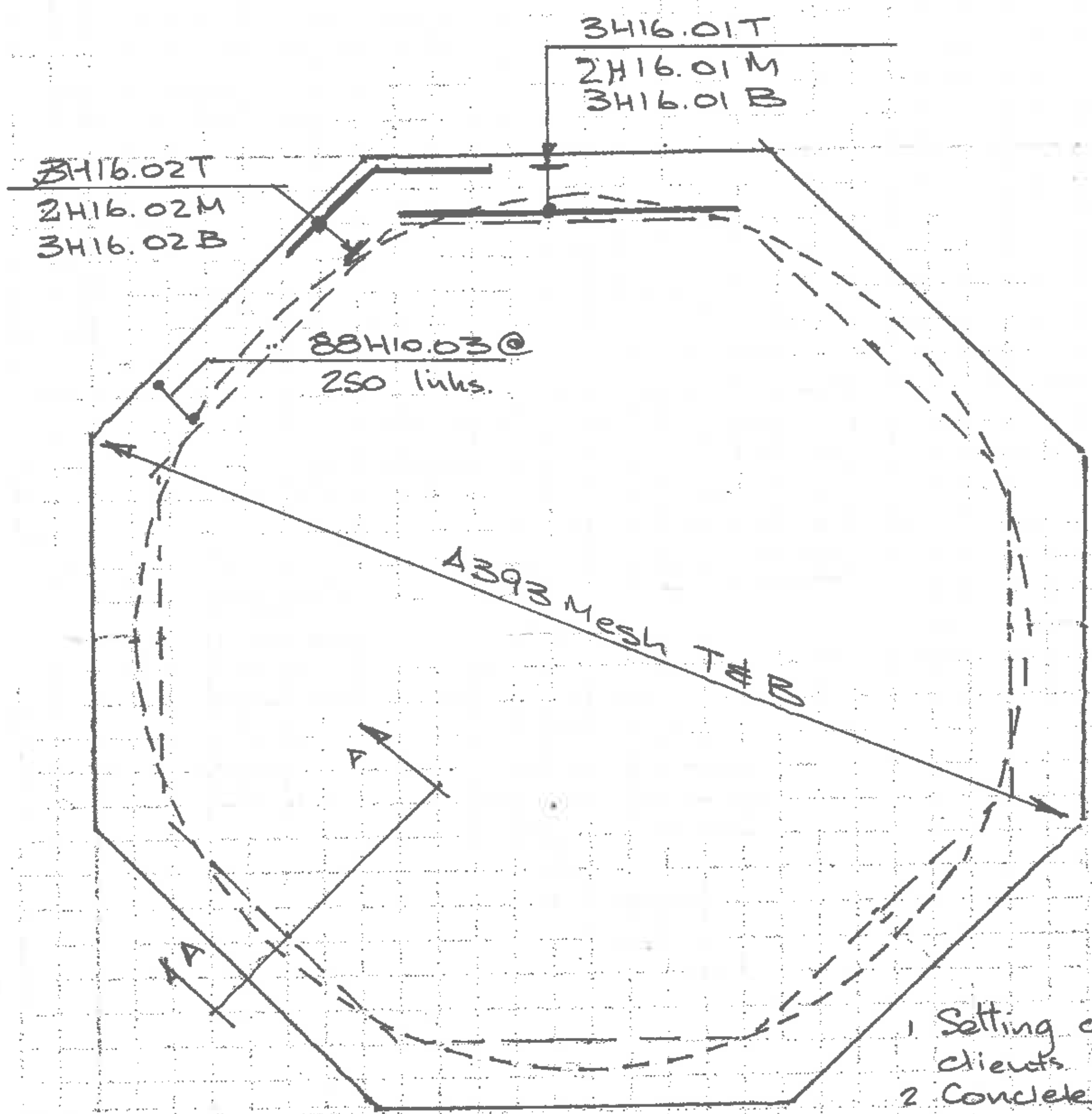
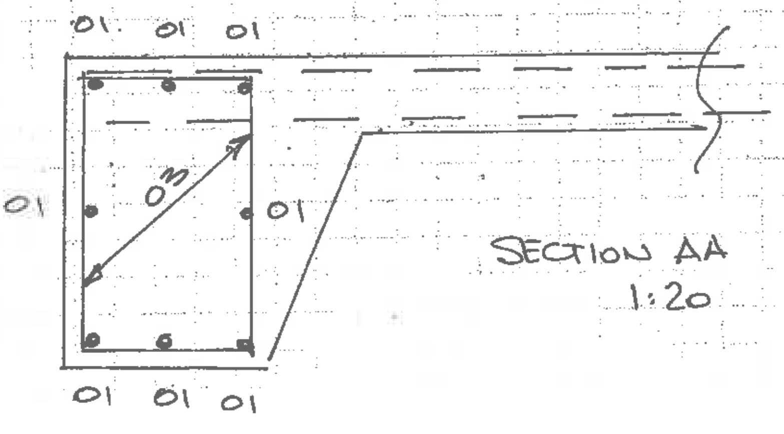
Project No: 15658	Sheet No: SK2	Rev.
Made By: JAG	Checked By:	
Date: DEC 15	Date:	

Project	ASHWELL ENTERPRISE PARK
Element	FIRE TANK FOUNDATIONS : REINFORCEMENT.



PLAN 1:50



1. Setting out & levels to clients instructions.
2. Concrete to be C35. Min. cement content 330kg/m³
3. Cover to steel 50mm.
4. Mesh laps 300mm, bottom layer to be cut where clashing with links.
5. Refer to BS1 for bending schedule.
6. Finish to be to tank manufacturers requirements for level & finish.
7. Mesh to be on chairs

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Project No: 15658	Sheet No: BS 1	Rev.
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Project	ASHWELL ENTERPRISE PARK.
Element	BENDING SCHEDULE TO BS 8666:2000

Member	Bar Mark	Type & Size	No. of Members	No. in each	Total	Length	Code	A	B	C	D	E/R	Comments
Edge Beam	01	H16	8	8	64	2400	00						
Corners	02	H16	8	8	64	1600	15	800	565				
links	03	H10		88	88	1850	51	500	350	100			