CALCULATION SHEET	Job No	3417-18
Project: ***UP HILL LONDON NW2 3QB***	Revision:	CC0
Title: ***HOARDING***	*Sheet:*	1
	Prepared by:	MAT
Customer: ***48 SHOOT UP HILL LTD***	*Checked by:*	TS
	Date:	13-06-2017

INDEPENDENT DESIGN HOUSE LTD

1. Description:

Revision:

CC0 - N/A

Aim:

Provide calculations for 2.5m high hoarding with posts embedded into the ground.
All set out on the drawing no. ***3418-18-P0.***

Loadings:

This structure has been designed in accordance with the following guidance:
- BS EN 1991-1-4:2005 - Wind Actions & TG20-13 Wind Guidance
- BS 5975:2008 - Code of practice for temp. works procedures and the permissible stress design of falsework
- TWf 2012:01 HOARDINGS: A guide to good practice

2. Loading:

2.1. Minimum notional horizonal load:

The minimum notional horizontal load applied to hoarding is:

$H_z := 0.74 \frac{kN}{m}$, acting at height of: $h_z := 1.2m$ above the base.

2.2. Wind load:

Hoarding dimnesions:

hoarding length: $l := 46m$

total length: $b := l = 46\,m$

bay width: $d := 10m$

hoarding height: $h := 2.5m$

Site location data:

altitude of the site: $A := 60m$

distance to shoreline: $dist_{sh} := 65km$

distance inside town terrain: $dist_{town} := 8km$

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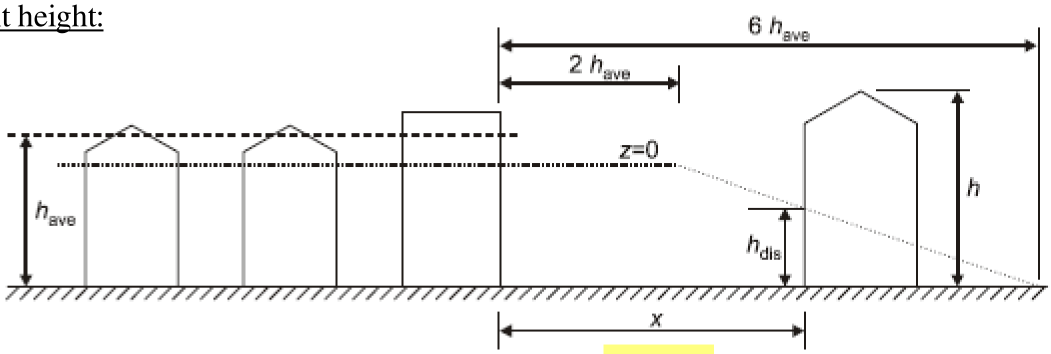
Displacement height:



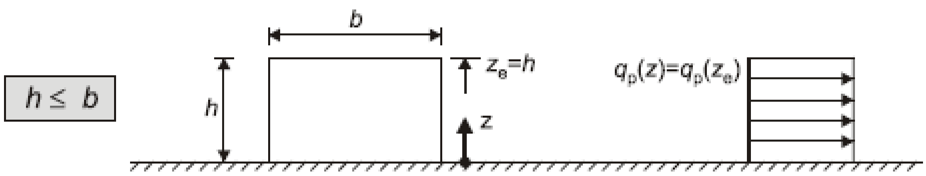
$h_{ave} := 0m$

$x := 0m$

$$h_{dis} := \begin{cases} \min(0.8h_{ave}, 0.6\cdot h) & \text{if } x \le 2\cdot h_{ave} \\ \min(1.2h_{ave} - 0.2x, 0.6\cdot h) & \text{if } x > 2h_{ave} \wedge x < 6.h_{ave} \\ 0 & \text{if } x \ge 6h_{ave} \end{cases} = 0\,m$$

Reference height for Wind Calculation:

$h = 2.5\,m \quad < \quad b = 46\,m$



reference height: $z_e := h = 2.5\,m$

Fundamental value of of basic wind velocity:

fundamental value of basic wind velocity before altitude correction: $v_{b.map} := 21.5\frac{m}{s}$ *[Figure NA.1] (see appendix A for details)*

altitude factor:

$$c_{alt} := \begin{cases} 1 + 0.001\frac{A}{m} & \text{if } z_e \le 10m \\ 1 + 0.001\frac{A}{m}\cdot\left(\frac{10m}{z_e}\right)^{0.2} & \text{if } z_e > 10m \end{cases} = 1.06$$

$$v_{b.0} := v_{b.map}\cdot c_{alt} = 22.79\frac{m}{s}$$

The basic wind velocity:

directional factor: $c_{dir} := 1.0$ *(for simplification)*

season factor: $c_{season} := 1.0$ *(for simplification)*

probability factor: $c_{prob} := 0.83$ *(for two-year return time)*

$$v_b := c_{prob} \cdot c_{dir} \cdot c_{season} \cdot v_{b.0} = 18.916 \frac{m}{s}$$

Basic velocity pressure:

air density (NA.2.18): $\rho := 1.226 \frac{kg}{m^3}$

$$q_b := \frac{1}{2} \cdot \rho \cdot v_b^2 = 0.219 \cdot kPa$$

Peak Velocity pressure:

Distance upwind to shoreline: $dist_{sh} = 65 \cdot km$

Distance inside town terrain: $dist_{town} = 8 \cdot km$

Reference height - displacement height: $z_e - h_{dis} = 2.5 m$

exposure factor: $c_e := 1.55$ *[Figure NA.7]* *(see appendix B for details)*

exposure factor for town terrain: $c_{e.T} := 0.64$ *[Figure NA.8]* *(see appendix B for details)*

(for country site terrain = 1.0)

FULL WIND

$$q_p := c_e \cdot c_{e.T} \cdot q_b = 0.218 \cdot kPa$$

WORKING WIND

$$q_{p.work} := 0.2kPa$$

Wind pressure on surfaces - free-standing wall:

solidity ratio: $\varphi := 1$

return corners: $rc := YES$

length to height ratio: $\frac{l}{h} = 18.4$

Table 7.9 — Recommended pressure coefficients $c_{p,net}$ for free-standing walls and parapets

Solidity	Zone		A	B	C	D
$\varphi = 1$	Without return corners	$\ell/h \le 3$	2,3	1,4	1,2	1,2
		$\ell/h = 5$	2,9	1,8	1,4	1,2
		$\ell/h \ge 10$	3,4	2,1	1,7	1,2
	with return corners of length $\ge h$ [a]		2,1	1,8	1,4	1,2
$\varphi = 0,8$			1,2	1,2	1,2	1,2

[a] Linear interpolation may be used for return corner lengths between 0,0 and h

Zone A: *Calculations may be neglected (Zone A is only 0.72m wide)*

Zone B:

$c_{pe.net.B} = 1.8$

$W_B := q_p \cdot c_{pe.net.B} = 0.392 \cdot kPa$

$W_{B.work} := q_{p.work} \cdot c_{pe.net.B} = 0.36 \cdot kPa$

zone lengths:

$l_{b.ac} := 2 \cdot h = 5\,m$

$l_b := l_{b.ac} - 0.3 \cdot h = 4.25\,m$

Zone C:

$c_{pe.net.C} = 1.4$

$W_C := q_p \cdot c_{pe.net.C} = 0.305 \cdot kPa$

$W_{C.work} := q_{p.work} \cdot c_{pe.net.C} = 0.28 \cdot kPa$

zone lengths:

$l_{c.ac} := 4 \cdot h = 10\,m$

$l_c := l_{c.ac} - l_{b.ac} = 5\,m$

Zone D:

$c_{pe.net.D} = 1.2$

$W_D := q_p \cdot c_{pe.net.D} = 0.261 \cdot kPa$

$W_{D.work} := q_{p.work} \cdot c_{pe.net.D} = 0.24 \cdot kPa$

zone lengths:

$l_{d.ac} := l = 46\,m$

$l_d := l - l_{c.ac} = 36\,m$

Zone $D_{FREE\ END}$:

$c_{pe.net.Dfe} := 2.1$

$W_{D.fe} := q_p \cdot c_{pe.net.Dfe} = 0.457 \cdot kPa$

$W_{Dfe.work} := q_{p.work} \cdot c_{pe.net.Dfe} = 0.42 \cdot kPa$

zone lengths:

$l_{d.fe} := 4 \cdot h = 10\,m$

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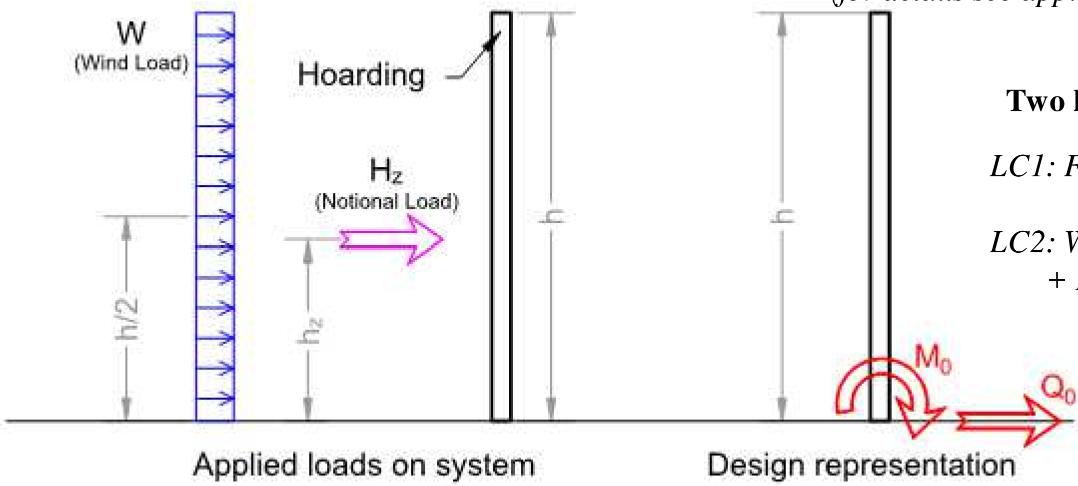
3. Post design:

Perm. BM and SF:

Post used: 75x200mm C24 timber beam

$M_{Rd} := 5.01 kNm$ $Q_{Rd} := 15.7 kN$

(for details see app. C)



Two load cases:

LC1: Full Wind

LC2: Working Wind + Lateral Load

Zone B:

Overturning moment about base per m run of hoarding: $M_{0.B} := \max\left[\left(W_B \cdot h\right)\cdot\frac{h}{2}, \left(W_{B.work}\cdot h\right)\cdot\frac{h}{2} + H_z\cdot h_z\right] = 2.013\cdot\frac{kNm}{m}$

Shear force in base per m run of hoarding: $Q_{0.B} := \max\left(W_B\cdot h, W_{B.work}\cdot h + H_z\right) = 1.64\cdot\frac{kN}{m}$

Max. possible post CRS: $CRS_B := \min\left(\frac{M_{Rd}}{M_{0.B}}, \frac{Q_{Rd}}{Q_{0.B}}\right) = 2.489\, m$ $CRS_B := 2.0m$

no. of bays: $n_B = 3$

Zone C:

Overturning moment about base per m run of hoarding: $M_{0.C} := \max\left[\left(W_C \cdot h\right)\cdot\frac{h}{2}, \left(W_{C.work}\cdot h\right)\cdot\frac{h}{2} + H_z\cdot h_z\right] = 1.763\cdot\frac{kNm}{m}$

Shear force in base per m run of hoarding: $Q_{0.C} := \max\left(W_C\cdot h, W_{C.work}\cdot h + H_z\right) = 1.44\cdot\frac{kN}{m}$

Max. possible post CRS: $CRS_C := \min\left(\frac{M_{Rd}}{M_{0.C}}, \frac{Q_{Rd}}{Q_{0.C}}\right) = 2.842\, m$ $CRS_C := 2.0m$

no. of bays: $n_C = 2$

Zone D:

Overturning moment about base per m run of hoarding: $M_{0.D} := \max\left[\left(W_D \cdot h\right)\cdot\frac{h}{2}, \left(W_{D.work}\cdot h\right)\cdot\frac{h}{2} + H_z\cdot h_z\right] = 1.638\cdot\frac{kNm}{m}$

Shear force in base per m run of hoarding: $Q_{0.D} := \max\left(W_D\cdot h, W_{D.work}\cdot h + H_z\right) = 1.34\cdot\frac{kN}{m}$

Max. possible post CRS: $CRS_D := \min\left(\frac{M_{Rd}}{M_{0.D}}, \frac{Q_{Rd}}{Q_{0.D}}\right) = 3.059\, m$ $CRS_D := 2.0m$

no. of bays: remainder

4. Horizontal rails design:

Perm. BM and SF:

Rails used: 50x75mm C16 timber beam

$M_{Rd} := 0.45kNm$ $Q_{Rd} := 4.18kN$

No. of rails used: $n := 4$

(for details see app. C)

Calculated rails centres: $CRS := \frac{h}{n-1} = 0.833\,m$

The design assumption for worst case for one central rail is either full wind or working wind with half min. notional horizontal load applied to a single rail.

Max. linear loads on a single rail in different wind zones:

$$q_B := \max\left(W_B \cdot CRS, W_{B.work} \cdot CRS + 0.5H_z\right) = 0.67 \cdot \frac{kN}{m}$$

$$q_C := \max\left(W_C \cdot CRS, W_{C.work} \cdot CRS + 0.5H_z\right) = 0.603 \cdot \frac{kN}{m}$$

$$q_D := \max\left(W_D \cdot CRS, W_{D.work} \cdot CRS + 0.5H_z\right) = 0.57 \cdot \frac{kN}{m}$$

Extreme bending moment values for different wind zones:

$$M_B := 0.125 \cdot q_B \cdot CRS_B^{\ 2} = 0.335 \cdot kNm$$

$$M_C := 0.125 \cdot q_C \cdot CRS_C^{\ 2} = 0.302 \cdot kNm$$

$$M_D := 0.125 \cdot q_D \cdot CRS_D^{\ 2} = 0.285 \cdot kNm$$

Moment of resistance:

$M_{Rd} = 0.45 \cdot kNm$

therefore = "OK"

Extreme shear force values for different wind zones:

$$Q_B := 0.625 \cdot q_B \cdot CRS_B = 0.838\,kN$$

$$Q_C := 0.625 \cdot q_C \cdot CRS_C = 0.754\,kN$$

$$Q_D := 0.625 \cdot q_D \cdot CRS_D = 0.713\,kN$$

Allowable shear force:

$Q_{Rd} = 4.18\,kN$

therefore = "OK"

5. Face material design:

Perm. BM and SF:

Plywood used: 18mm FSC Grade

$$M_{Rd} := 0.456 \frac{kNm}{m} \qquad Q_{Rd} := 6.34 \frac{kN}{m}$$

Design for worst case loading of either panel robustness loading of 1.5 kN/m² or the effect of the min. notional horizontal load mid-way between rail, assuming face material simply supported.

$$M_f := \max\left(0.125 \cdot 1.5 \frac{kN}{m^2} \cdot CRS^2, 0.125 W_{B.work} \cdot CRS^2 + 0.25 \cdot H_z \cdot CRS\right) = 0.185 \cdot \frac{kNm}{m}$$

$$Q_f := \max\left(0.5 \cdot 1.5 \frac{kN}{m^2} \cdot CRS, 0.5 W_{B.work} \cdot CRS + 0.5 \cdot H_z\right) = 0.625 \cdot \frac{kN}{m}$$

therefore = "OK"

6. Connection of ply to rails:

NOTE: For connection design wind in zone A (worst case) should be considered.

Zone A:

$c_{pe.net.A} = 2.1$

$W_A := q_p \cdot c_{pe.net.A} = 0.457 \cdot kPa$

$W_{A.work} := q_{p.work} \cdot c_{pe.net.A} = 0.42 \cdot kPa$

zone lengths:

$l_a := 0.3 \cdot h = 0.75\,m$

Max. linear load on a single rail in wind zone A:

$$q_A := \max\left(W_A \cdot CRS, W_{A.work} \cdot CRS + H_z\right) = 1.09 \cdot \frac{kN}{m}$$

Connection used: 6mm wood screws, 50mm long

Basic withdrawal load per mm of penetration:

$$F := 18.2 \frac{N}{mm}$$

Assumed screws centres: $crs := 300mm$

Point side penetration: $e := 50mm - 18mm = 32 \cdot mm$

Design factors : $K_{52} := 1.25$ (very short term loading) $\quad K_{53} := 0.7$ (Class 3)

Permissible load per metre: $$q_{Rd} := \frac{e \cdot F \cdot K_{52} \cdot K_{53}}{crs} = 1.699 \cdot \frac{kN}{m} \quad > \quad q_A = 1.09 \cdot \frac{kN}{m}$$

therefore = "OK"

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7. Connection of rails to post:

$CRS_A := CRS_B = 2\,m$

NOTE: The rails are not continuous past the post, hence the loaded length is halved.

Max. point load on a single post in wind zone A:

$$P := \max\left(W_A \cdot CRS, W_{A.work} \cdot CRS + H_z\right) \frac{CRS_A}{2} = 1.09 \cdot kN$$

Basic withdrawal load per mm of penetration:

$$F := 22.1 \frac{N}{mm}$$

Connection used: 6mm wood screws, 150mm long

Assumed no. of screws: $n := 1$

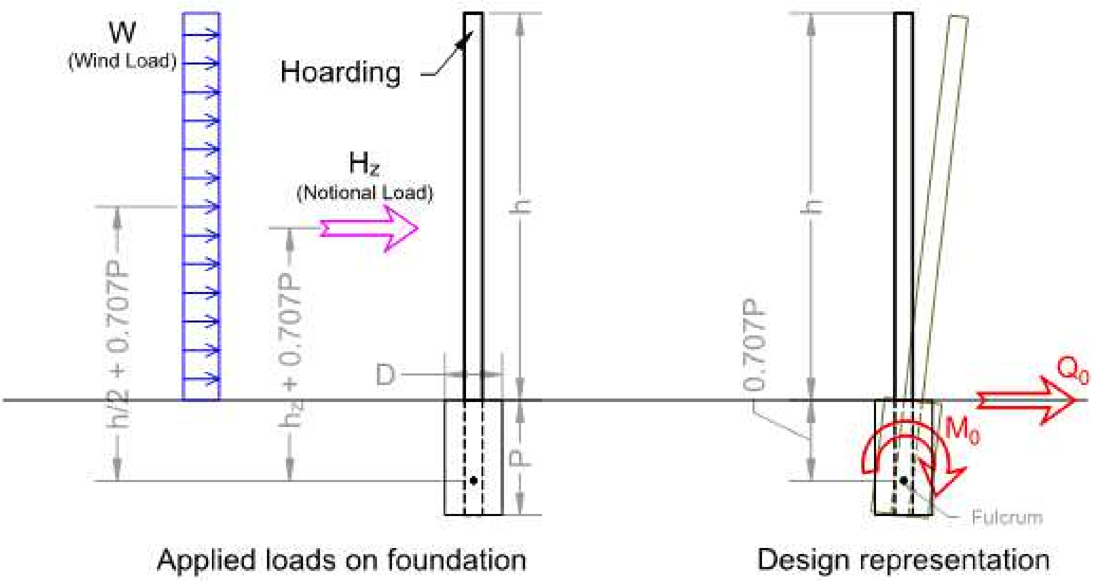
Point side penetration: $e := 150mm - 75mm = 75 \cdot mm$

Design factors : $K_{52} := 1.25$ (very short term loading) $K_{53} := 0.7$ (Class 3)

Permissible load per connect.: $P_{Rd} := n \cdot e \cdot F \cdot K_{52} \cdot K_{53} = 1.45 \cdot kN \quad > \quad P = 1.09 \cdot kN$

therefore = "OK"

8. Foundation design:



Max. overturning forces about post base:

$$M_0 := \max\left(M_{0.B} \cdot CRS_B, M_{0.C} \cdot CRS_C, M_{0.D} \cdot CRS_D\right) = 4.026 \cdot kNm$$

$$Q_0 := \max\left(Q_{0.B} \cdot CRS_B, Q_{0.C} \cdot CRS_C, Q_{0.D} \cdot CRS_D\right) = 3.28 \cdot kN$$

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Ground resistance moment:

Ground factor (for average quality of the ground):
[in accordance with:TWf2012: 01, Table D1]

$G := 390\frac{kN}{m^2}$

Minimum effective width of concreted foundation: $D := 0.40m$

Planting depth of the post from ground level: $P := 0.85m$

$$M_g := \frac{G \cdot D \cdot P^3}{10m} = 9.58 \cdot kNm$$

Max. overturning moment about fulcrum point: *(with 1.5 factor of safety)*

$$M_O := \left[M_0 + \left(0.707 \cdot Q_0 \cdot P\right)\right] \cdot 1.5 = 8.996 \cdot kNm \quad < \quad M_g = 9.58 \cdot kNm$$

therefore = "OK"

9. Summary:

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* Use **75x200 C24** constructional sawn timber posts at crs: **2.00m** (to all wind zones);
* Use **4No. 50x75 C16** constructional sawn timber rails at **800mm** centres;
* Face material assumed as **18mm FSC Grade Plywood ;**
* Use **6mm wood screws 50mm long** for the ply to rail connection at **300mm** centres;
* Use **1No. 6mm wood screws 150mm long** per rail to post connection;
* Posts to be embedded in to the ground in **400mm dia. hole, 0.85m deep** and infilled with concrete

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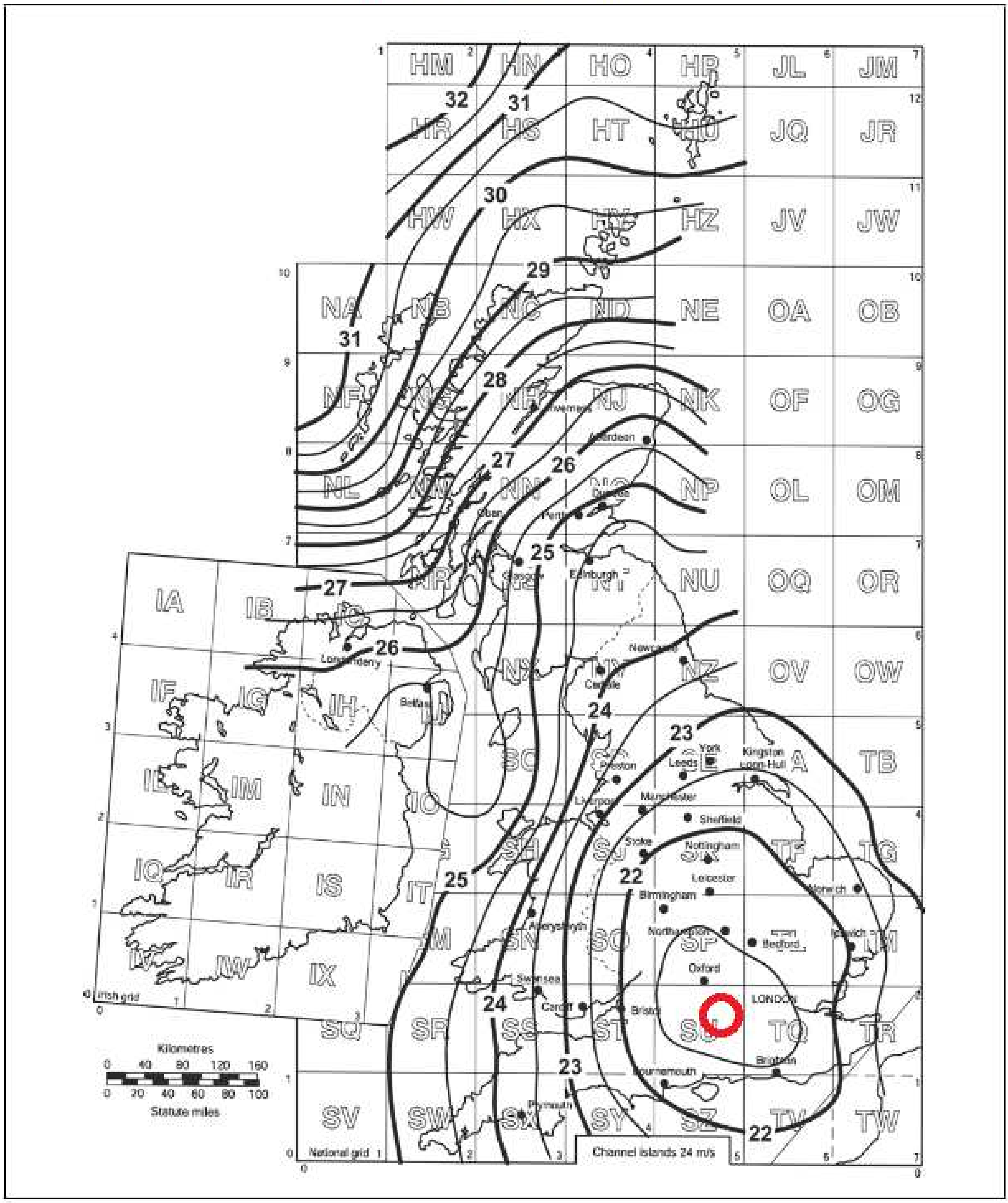
APPENDIX A

Figure NA.1 Value of fundamental basic wind velocity $v_{b,map}$ (m/s) before the altitude correction is applied



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APPENDIX B

Figure NA.8 Values of exposure correction factor $c_{e,T}$ for sites in Town terrain

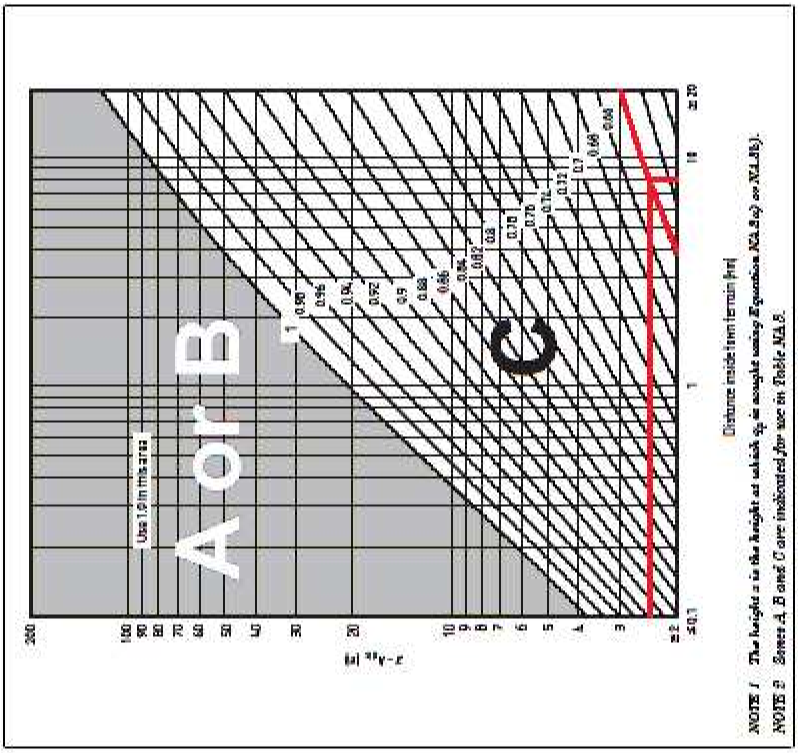
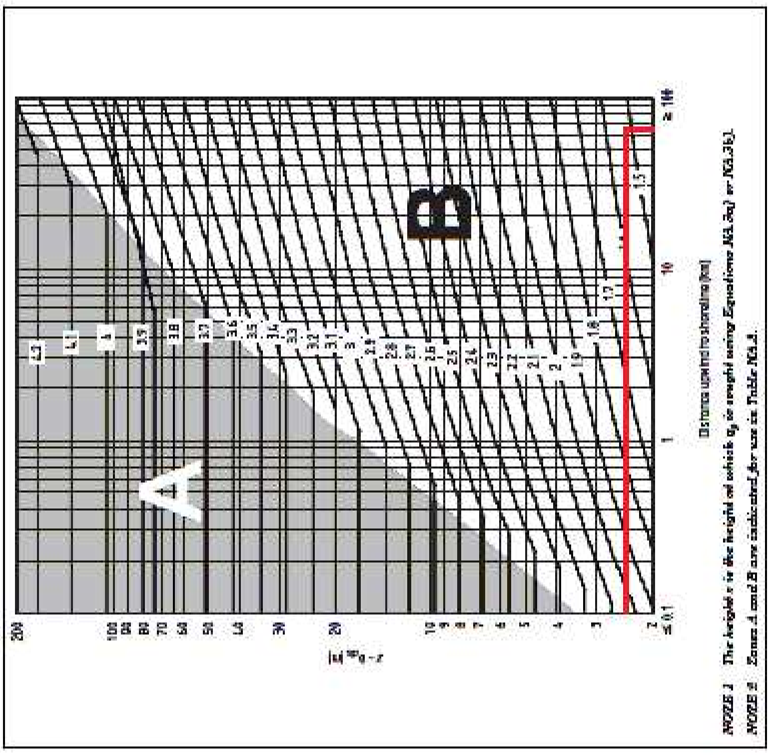


Figure NA.7 Values of $c_e(z)$



APPENDIX C

Allowable internal forces for timber beams *(according to BS 5268-2:2002)*

75x200mm C24 timber posts

Dimensions of cross-section: $a = 3 \cdot in$ $b = 8 \cdot in$

Section area: $A_s := a \cdot b = 140.4 \cdot cm^2$

Moment of inertia: $I_y := \frac{a \cdot b^3}{12} = 4448.925 \cdot cm^4$

Section modulus: $W_y := \frac{a \cdot b^2}{6} = 456.3 \cdot cm^3$

Timber_grade = "C24"

Bending stress parallel to grain: $fZ = 7.5 \cdot \frac{N}{mm^2}$

Shear stress parallel to grain (service class 3): $qA = 0.71 \cdot \frac{N}{mm^2}$

Mean modulus of elasticity (service class 3): $E_{0.mean} = 8640 \cdot \frac{N}{mm^2}$

Minimum modulus of elasticity: $E_{min} = 5760 \cdot \frac{N}{mm^2}$

Aplication = "load sharing - hoarding"

Factor converting service classes 1 and 2 strength classes to service class 3 (bending): $K_{2b} := 0.8$

Factor converting service classes 1 and 2 strength classes to service class 3 (shear): $K_{2s} := 0.9$

Duration of load factor: $K_3 = 1.75$

Bearing stress factor: $K_4 := 1.0$

Form factor: $K_6 := 1.0$

Depth factor: $K_7 = 1.046$

Load sharing factor: $K_8 = 1$

PERMISSIBLE STRESSES

Moment of resistance:

$M_{RdP} := fZ \cdot W_y \cdot K_{2b} \cdot K_3 \cdot K_4 \cdot K_6 \cdot K_7 \cdot K_8 = 5.01 \cdot kN \cdot m$

Shear load:

$V_{RdP} := qA \cdot A_s K_{2s} \cdot K_3 \cdot K_4 \cdot K_6 \cdot K_8 = 15.7 \cdot kN$

50x75mm C16 timber rails

Dimensions of cross-section: $a = 2 \cdot in$ $b = 3 \cdot in$

Section area: $A_s := a \cdot b = 33.84 \cdot cm^2$

Moment of inertia: $I_y := \frac{a \cdot b^3}{12} = 146.189 \cdot cm^4$

Section modulus: $W_y := \frac{a \cdot b^2}{6} = 40.6 \cdot cm^3$

Timber_grade = "C16"

Bending stress parallel to grain: $fZ = 5.3 \cdot \frac{N}{mm^2}$

Shear stress parallel to grain (service class 3): $qA = 0.67 \cdot \frac{N}{mm^2}$

Mean modulus of elasticity (service class 3): $E_{0.mean} = 7040 \cdot \frac{N}{mm^2}$

Minimum modulus of elasticity: $E_{min} = 4640 \cdot \frac{N}{mm^2}$

Aplication = "load sharing - hoarding"

Factor converting service classes 1 and 2 strength classes to service class 3 (bending): $K_{2b} := 0.8$

Factor converting service classes 1 and 2 strength classes to service class 3 (shear): $K_{2s} := 0.9$

Duration of load factor: $K_3 = 1.75$

Bearing stress factor: $K_4 := 1.0$

Form factor: $K_6 := 1.0$

Depth factor: $K_7 = 1.165$

Load sharing factor: $K_8 = 1$

Plywood used: **18mm Finish plywood - sanded (9 veneers)**

Characteristic mean modulus of elasticity in bending - face grain perpendicular to span: $E_{m.ply} := 3350 \frac{N}{mm^2}$

Modification factor for creep deformation and service class (table 38 BS EN 5268-2): $k_{def} := 0.0$

Duration of load and servce class factor for plywood (short and very short term - table 39 BS EN 5268-2): $K_{36} := 1.43$

Grade modulus value: $E_{d.ply} := \frac{E_{m.ply}}{1 + k_{def}} \cdot K_{36} = 4790.5 \cdot \frac{N}{mm^2}$

Area of ply in the face contact with rail: $A_{ply} := 18mm \cdot a = 8.46 \cdot cm^2$

Rail and plywood modulus of elasticity ratio: $\alpha := \frac{E_{0.mean}}{E_{d.ply}} = 1.47$

Moment of inertia of ply section: $I_{y.ply} := \frac{a \cdot (18mm)^3}{12} = 2.284 \cdot cm^4$

Transformed area of the timber component: $A_i := A_s + \frac{A_{ply}}{\alpha} = 39.597 \cdot cm^2$

Distance between centroid of ply section and centroid of rail section: $y_{dist} := \frac{b}{2} + \frac{18mm}{2} = 4.5 \cdot cm$

Distance between centroid of rail section and centroid of transformed timber component: $y_r := \frac{A_{ply}}{\alpha \cdot A_i} \cdot y_{dist} = 6.542 \cdot mm$

Distance between centroid of ply section and centroid of transformed timber component: $y_{ply} := \frac{A_s}{A_i} \cdot y_{dist} = 3.846 \cdot cm$

Distance between centroid of transformed timber component and top fibre of the section: $y_u := y_{ply} + \frac{18mm}{2} = 4.746 \cdot cm$

Distance between centroid of transformed timber component and bottom fibre of the section: $y_d := y_r + \frac{b}{2} = 4.254 \cdot cm$

Moment of inertia of transformed timber component: $I_c := I_y + \frac{I_{y.ply}}{\alpha} \ldots + A_s \cdot y_{dist} \cdot y_r = 247.369 \cdot cm^4$

Section modulus - top fibres: $W_{y.u} := \frac{I_c}{y_u} = 52.124 \cdot cm^3$

Section modulus - bottom fibres: $W_{y.d} := \frac{I_c}{y_d} = 58.147 \cdot cm^3$

Min. section modulus: $W_y := \min(W_{y.u}, W_{y.d}) = 52.1 \cdot cm^3$

Section area: $A_s := A_i = 39.597 \cdot cm^2$

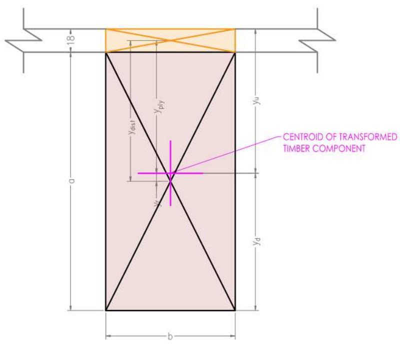
PERMISSIBLE STRESSES

Moment of resistance:

$M_{Rd} := fZ \cdot W_y \cdot K_{2b} \cdot K_3 \cdot K_4 \cdot K_6 \cdot K_7 \cdot K_8 = 0.45 \cdot kN \cdot m$

Shear load:

$V_{Rd} := qA \cdot A_s K_{2s} \cdot K_3 \cdot K_4 \cdot K_6 \cdot K_8 = 4.18 \cdot kN$



geometric properties of transformed timber component

CALCULATION SHEET	Job No	3417-18
Project: ***UP HILL LONDON NW2 3QB***	Revision:	CC0
Title: ***HOARDING***	Sheet:	16
	Prepared by:	MAT
Customer: ***48 SHOOT UP HILL LTD***	Checked by:	TS
	Date:	13-06-2017

1. Description:

Revision:

CC0 - N/A

Aim:

Provide calculations for 2.5m high hoarding (on extension) with posts fixed to brick wall. All set out on the drawing no. ***3417-18-P0***

Loadings:

This structure has been designed in accordance with the following guidance:
- BS EN 1991-1-4:2005 - Wind Actions & TG20-13 Wind Guidance
- BS 5975:2008 - Code of practice for temp. works procedures and the permissible stress design of falsework
- TWf 2012:01 HOARDINGS: A guide to good practice

2. Loading:

2.1. Minimum notional horizontal load:

The minimum notional horizontal load applied to hoarding is:

$H_z := 0.74 \frac{kN}{m}$, acting at height of: $h_z := 1.2m$ above the base.

2.2. Wind load:

Hoarding dimensions:

hoarding length: $l := 46m$

total length: $b := l = 46\,m$

bay width: $d := 10m$

hoarding height: $h := 2.5m$

wall height: $h_{wall} := 980mm$

loaded area high: $h_{ld} := h - h_{wall} = 1.52\,m$

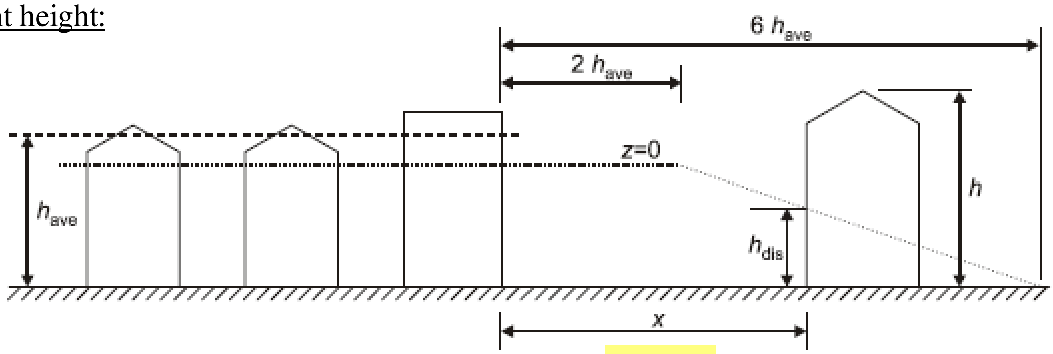
Site location data:

altitude of the site: $A := 60m$

distance to shoreline: $dist_{sh} := 65km$

distance inside town terrain: $dist_{town} := 8km$

Displacement height:



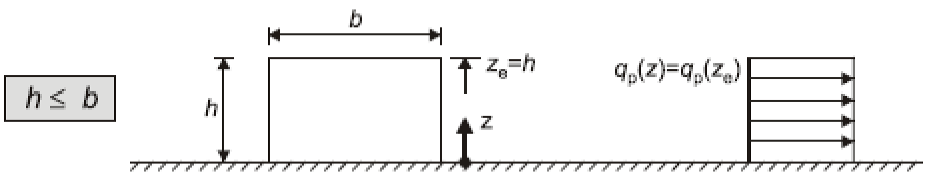
$h_{ave} := 0m$

$x := 0m$

$$h_{dis} := \begin{cases} \min(0.8h_{ave}, 0.6\cdot h) & \text{if } x \le 2\cdot h_{ave} \\ \min(1.2h_{ave} - 0.2x, 0.6\cdot h) & \text{if } x > 2h_{ave} \wedge x < 6.h_{ave} \\ 0 & \text{if } x \ge 6h_{ave} \end{cases} = 0\,m$$

Reference height for Wind Calculation:

$h = 2.5\,m \quad < \quad b = 46\,m$



reference height: $z_e := h = 2.5\,m$

Fundamental value of of basic wind velocity:

fundamental value of basic wind velocity before altitude correction: $v_{b.map} := 21.5\frac{m}{s}$ *[Figure NA.1]* *(see appendix A for details)*

altitude factor:

$$c_{alt} := \begin{cases} 1 + 0.001\frac{A}{m} & \text{if } z_e \le 10m \\ 1 + 0.001\frac{A}{m}\cdot\left(\frac{10m}{z_e}\right)^{0.2} & \text{if } z_e > 10m \end{cases} = 1.06$$

$$v_{b.0} := v_{b.map}\cdot c_{alt} = 22.79\frac{m}{s}$$

The basic wind velocity:

directional factor: $c_{dir} := 1.0$ *(for simplification)*

season factor: $c_{season} := 1.0$ *(for simplification)*

probability factor: $c_{prob} := 0.83$ *(for two-year return time)*

$$v_b := c_{prob} \cdot c_{dir} \cdot c_{season} \cdot v_{b.0} = 18.916 \frac{m}{s}$$

Basic velocity pressure:

air density (NA.2.18): $\rho := 1.226 \frac{kg}{m^3}$

$$q_b := \frac{1}{2} \cdot \rho \cdot v_b^2 = 0.219 \cdot kPa$$

Peak Velocity pressure:

Distance upwind to shoreline: $dist_{sh} = 65 \cdot km$

Distance inside town terrain: $dist_{town} = 8 \cdot km$

Reference height - displacement height: $z_e - h_{dis} = 2.5\,m$

exposure factor: $c_e := 1.55$ *[Figure NA.7]* *(see appendix B for details)*

exposure factor for town terrain: $c_{e.T} := 0.64$ *[Figure NA.8]* *(see appendix B for details)*

(for country site terrain = 1.0)

FULL WIND

$$q_p := c_e \cdot c_{e.T} \cdot q_b = 0.218 \cdot kPa$$

WORKING WIND

$$q_{p.work} := 0.2kPa$$

Wind pressure on surfaces - free-standing wall:

solidity ratio: $\varphi := 1$

return corners: $rc := YES$

length to height ratio: $\frac{l}{h} = 18.4$

Table 7.9 — Recommended pressure coefficients $c_{p,net}$ for free-standing walls and parapets

Solidity	Zone		A	B	C	D
$\varphi = 1$	Without return corners	$\ell/h \le 3$	2,3	1,4	1,2	1,2
		$\ell/h = 5$	2,9	1,8	1,4	1,2
		$\ell/h \ge 10$	3,4	2,1	1,7	1,2
	with return corners of length $\ge h$ [a]		2,1	1,8	1,4	1,2
$\varphi = 0,8$			1,2	1,2	1,2	1,2

[a] Linear interpolation may be used for return corner lengths between 0,0 and h

Zone A:

$c_{pe.net.A} = 2.1$

$W_A := q_p \cdot c_{pe.net.A} = 0.457 \cdot kPa$

$W_{A.work} := q_{p.work} \cdot c_{pe.net.A} = 0.42 \cdot kPa$

zone lengths:

$l_a := 0.3 \cdot h = 0.75\,m$

Zone B:

$c_{pe.net.B} = 1.8$

$W_B := q_p \cdot c_{pe.net.B} = 0.392 \cdot kPa$

$W_{B.work} := q_{p.work} \cdot c_{pe.net.B} = 0.36 \cdot kPa$

zone lengths:

$l_{b.ac} := 2 \cdot h = 5\,m$

$l_b := l_{b.ac} - l_a = 4.25\,m$

Zone C:

$c_{pe.net.C} = 1.4$

$W_C := q_p \cdot c_{pe.net.C} = 0.305 \cdot kPa$

$W_{C.work} := q_{p.work} \cdot c_{pe.net.C} = 0.28 \cdot kPa$

zone lengths:

$l_{c.ac} := 4 \cdot h = 10\,m$

$l_c := l_{c.ac} - l_{b.ac} = 5\,m$

Zone D:

$c_{pe.net.D} = 1.2$

$W_D := q_p \cdot c_{pe.net.D} = 0.261 \cdot kPa$

$W_{D.work} := q_{p.work} \cdot c_{pe.net.D} = 0.24 \cdot kPa$

zone lengths:

$l_{d.ac} := l = 46\,m$

$l_d := l - l_{c.ac} = 36\,m$

Zone $D_{FREE\ END}$:

$c_{pe.net.Dfe} := 2.1$

$W_{D.fe} := q_p \cdot c_{pe.net.Dfe} = 0.457 \cdot kPa$

$W_{Dfe.work} := q_{p.work} \cdot c_{pe.net.Dfe} = 0.42 \cdot kPa$

zone lengths:

$l_{d.fe} := 4 \cdot h = 10\,m$

3. Post design:

Perm. BM and SF:

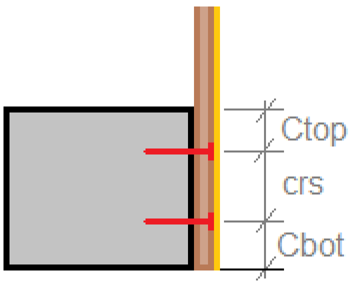
Post used: 75x200mm C24 timber beam $M_{Rd} := 5.01kNm$ $Q_{Rd} := 15.7kN$

Connection information: *(for details see app. C)*

$c_{top} := 125mm$ *- bolt to upper wall edge distance*

$c_{bot} := 125mm$ *- bolt to lower wall edge distance*

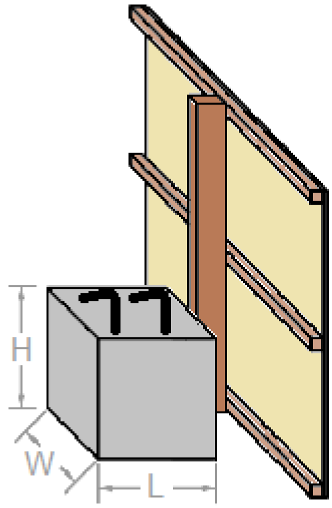
$crs_{bolt} := h_{wall} - c_{top} - c_{bot} = 0.73\,m$ *- bolt centres (except bolt in the middle)*



Two load cases:

LC1: Full Wind

LC2: Working Wind + Lateral Load



Post cantilever length: $p := h - h_{wall} + c_{top} = 1.645\,m$

Notional load lever arm: $p_z := \max(p + h_z - h, 0m) = 0.345\,m$

Zone B:

Max. bending moment in post per m run of hoarding:

$$M_{P.B} := \max\left[\left(W_B \cdot h_{ld}\right)\cdot\left(0.5h_{ld} + c_{top}\right), \left(W_{B.work} \cdot h_{ld}\right)\cdot\left(0.5h_{ld} + c_{top}\right) + H_z \cdot p_z\right]$$

$$M_{P.B} = 0.74\,kN$$

Max. shear force in post per m run of hoarding: $Q_{P.B} := \max\left(W_B \cdot h_{ld}, W_{B.work} \cdot h_{ld} + H_z\right) = 1.287 \cdot \frac{kN}{m}$

Max. possible posts CRS: $CRS'_B := \min\left(\frac{M_{Rd}}{M_{P.B}}, \frac{Q_{Rd}}{Q_{P.B}}\right) = 6.774\,m$ $CRS_B := 2m$

no. of bays: $n_B = 3$

Zone C:

Max. bending moment in post per m run of hoarding:

$$M_{P.C} := \max\left[\left(W_C \cdot h_{ld}\right)\cdot\left(0.5h_{ld} + c_{top}\right), \left(W_{C.work} \cdot h_{ld}\right)\cdot\left(0.5h_{ld} + c_{top}\right) + H_z \cdot p_z\right]$$

$$M_{P.C} = 0.632\,kN$$

Max. shear force in post per m run of hoarding: $Q_{P.C} := \max\left(W_C \cdot h_{ld}, W_{C.work} \cdot h_{ld} + H_z\right) = 1.166 \cdot \frac{kN}{m}$

Max. possible posts CRS: $CRS'_C := \min\left(\frac{M_{Rd}}{M_{P.C}}, \frac{Q_{Rd}}{Q_{P.C}}\right) = 7.928\,m$ $CRS_C := 2m$

no. of bays: $n_C = 2$

Zone D:

Max. bending moment in post per m run of hoarding:

$$M_{P.D} := \max\left[\left(W_D \cdot h_{ld}\right)\cdot\left(0.5h_{ld} + c_{top}\right), \left(W_{D.work} \cdot h_{ld}\right)\cdot\left(0.5h_{ld} + c_{top}\right) + H_z \cdot p_z\right]$$

$$M_{P.D} = 0.578\,kN$$

Max. shear force in post per m run of hoarding: $Q_{P.D} := \max\left(W_D \cdot h_{ld}, W_{D.work} \cdot h_{ld} + H_z\right) = 1.105 \cdot \frac{kN}{m}$

Max. possible posts CRS: $CRS'_D := \min\left(\frac{M_{Rd}}{M_{P.D}}, \frac{Q_{Rd}}{Q_{P.D}}\right) = 8.666\,m$ $\quad CRS_D := 2m$

no. of bays: remainder

Zone D$_{\text{FREE END}}$:

Max. bending moment in post per m run of hoarding:

$$M_{P.D.fe} := \max\left[\left(W_{D.fe} \cdot h_{ld}\right)\cdot\left(0.5h_{ld} + c_{top}\right), \left(W_{Dfe.work} \cdot h_{ld}\right)\cdot\left(0.5h_{ld} + c_{top}\right) + H_z \cdot p_z\right]$$

$$M_{P.D.fe} = 0.82\,kN$$

Max. shear force in post per m run of hoarding: $Q_{P.D.fe} := \max\left(W_{D.fe} \cdot h_{ld}, W_{Dfe.work} \cdot h_{ld} + H_z\right) = 1.378 \cdot \frac{kN}{m}$

Max. possible posts CRS: $CRS_{D.fe} := \min\left(\frac{M_{Rd}}{M_{P.D.fe}}, \frac{Q_{Rd}}{Q_{P.D.fe}}\right) = 6.108\,m$

$CRS_{D.fe} := 2m$

no. of bays: $n_{Dfe} = 5$

4. Horizontal rails design:

Perm. BM and SF:

Rails used: 50x75mm C16 timber beam $\quad M_{Rd} := 0.45kNm \quad Q_{Rd} := 4.18kN$

No. of rails used: $n := 3$ $\quad$ *(for details see app. C)*

Calculated rails centres: $CRS := \frac{h_{ld}}{n-1} = 0.76\,m$

Max. linear loads on a single rail in different wind zones:

$$q_B := \max\left(W_B \cdot CRS, W_{B.work} \cdot CRS + 0.5H_z\right) = 0.644 \cdot \frac{kN}{m}$$

$$q_C := \max\left(W_C \cdot CRS, W_{C.work} \cdot CRS + 0.5H_z\right) = 0.583 \cdot \frac{kN}{m}$$

$$q_D := \max\left(W_D \cdot CRS, W_{D.work} \cdot CRS + 0.5H_z\right) = 0.552 \cdot \frac{kN}{m}$$

$$q_{Dfe} := \max\left(W_{D.fe} \cdot CRS, W_{Dfe.work} \cdot CRS + 0.5H_z\right) = 0.689 \cdot \frac{kN}{m}$$

The design assumption for worst case for one central rail is either full wind or working wind with half min. notional horizontal load applied to a single rail.

Extreme bending moment values for different wind zones:

$$M_B := 0.125 \cdot q_B \cdot CRS_B^{\,2} = 0.322 \cdot kNm$$

$$M_C := 0.125 \cdot q_C \cdot CRS_C^{\,2} = 0.291 \cdot kNm$$

$$M_D := 0.125 \cdot q_D \cdot CRS_D^{\,2} = 0.276 \cdot kNm$$

$$M_{Dfe} := 0.125 \cdot q_{Dfe} \cdot CRS_{D.fe}^{\,2} = 0.345 \cdot kNm$$

Moment of resistance:

$$M_{Rd} = 0.45 \cdot kNm$$

therefore = "OK"

Extreme shear force values for different wind zones:

$$Q_B := 0.625 \cdot q_B \cdot CRS_B = 0.805\,kN$$

$$Q_C := 0.625 \cdot q_C \cdot CRS_C = 0.729\,kN$$

$$Q_D := 0.625 \cdot q_D \cdot CRS_D = 0.691\,kN$$

$$Q_{Dfe} := 0.625 \cdot q_{Dfe} \cdot CRS_{D.fe} = 0.862\,kN$$

Allowable shear force:

$$Q_{Rd} = 4.18\,kN$$

therefore = "OK"

5. Face material design:

Perm. BM and SF:

Plywood used: 18mm FSC Grade

$$M_{Rd} := 0.456 \frac{kNm}{m} \qquad Q_{Rd} := 6.34 \frac{kN}{m}$$

Design for worst case loading of either panel robustness loading of 1.5 kN/m² or the effect of the min. notional horizontal load mid-way between rail, assuming face material simply supported.

$$M_f := \max\left(0.125 \cdot 1.5 \frac{kN}{m^2} \cdot CRS^2, 0.125 W_A \cdot CRS^2\right) = 0.108 \cdot \frac{kNm}{m}$$

$$Q_f := \max\left(0.5 \cdot 1.5 \frac{kN}{m^2} \cdot CRS, 0.5 W_A \cdot CRS\right) = 0.57 \cdot \frac{kN}{m}$$

therefore = "OK"

6. Connection of ply to rails:

For connection design wind in zone A (worst case) should be considered.

Zone A:

$c_{pe.net.A} = 2.1$

zone lengths:

$l_a = 0.75\,m$

$W_A = 0.457 \cdot kPa$

$W_{A.work} = 0.42 \cdot kPa$

Max. linear load on a single rail in wind zone A:

$$q_A := \max\left(W_A \cdot CRS, W_{A.work} \cdot CRS + H_z\right) = 1.059 \cdot \frac{kN}{m}$$

Connection used: 6mm wood screws, 50mm long

Basic withdrawal load per mm of penetration:

$F := 18.2 \frac{N}{mm}$

Assumed screws centres: $crs := 300mm$

Point side penetration: $e := 50mm - 18mm = 32 \cdot mm$

Design factors : $K_{52} := 1.25$ (very short term loading) $K_{53} := 0.7$ (Class 3)

Permissible load per metre: $q_{Rd} := \frac{e \cdot F \cdot K_{52} \cdot K_{53}}{crs} = 1.699 \cdot \frac{kN}{m}$ > $q_A = 1.059 \cdot \frac{kN}{m}$

therefore = "OK"

7. Connection of rails to post:

$CRS_A := CRS_B = 2\,m$

NOTE: *the rails are not continuous past the post, hence the loaded length is halved.*

Max. point load on a single post in wind zone A:

$$P := \max\left(W_A \cdot CRS, W_{A.work} \cdot CRS + H_z\right) \frac{CRS_A}{2} = 1.059 \cdot kN$$

Connection used: 6mm wood screws, 150mm long

Basic withdrawal load per mm of penetration:

$F := 22.1 \frac{N}{mm}$

Assumed no. of screws: $n := 1$

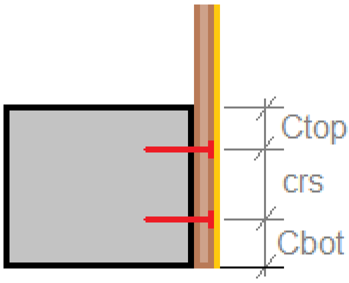
Point side penetration: $e := 150mm - 75mm = 75 \cdot mm$

Design factors : $K_{52} := 1.25$ (very short term loading) $K_{53} := 0.7$ (Class 3)

Permissible load per connect.: $P_{Rd} := n \cdot e \cdot F \cdot K_{52} \cdot K_{53} = 1.45 \cdot kN$ > $P = 1.059 \cdot kN$

therefore = "OK"

8. Check withdrawal on connection bolts to block:



Connection information:

$c_{top} = 125\,mm$ *- bolt to upper wall edge distance*

$c_{bot} = 125\,mm$ *- bolt to lower wall edge distance*

$crs_{bolt} := h_{wall} - c_{top} - c_{bot} = 0.73\,m$ *- bolt centres (except bolt in the middle)*

Max. bending moment at top bolt position:

$$M_{bolt} := \max\left(M_{P.B} \cdot CRS_B, M_{P.C} \cdot CRS_C, M_{P.D} \cdot CRS_D, M_{P.D.fe} \cdot CRS_{D.fe}\right) = 1.641 \cdot kNm$$

Max. withdrawal force on bolts: *Allowable WF for M8 Excalibur bolts with edge reduction factor*

$$F_w := \frac{M_{bolt}}{crs_{bolt} + c_{bot}} = 1.919 \cdot kN \quad < \quad F_{w.Rd} := 1 \cdot 2.73kN = 2.73\,kN$$

therefore = "OK"

Characteristic value of compression perpendicular for timber post:

$f_{c.90.k} := 2.5MPa$ *(BS EN 338:2009)*

$k_{mod} := 0.7$ *(Solid timber, service class 3, short term action)*

$\gamma_M := 1.3$ *(Recommended partial factor of material properties & resistances)*

Design value of compression perpendicular for timber post:

$$f_{c.90.d} := f_{c.90.k} \cdot \frac{k_{mod}}{\gamma_M} = 1.346 \cdot MPa$$

$k_{c.90} := 1.5$ *(For solid timber member on discrete supports loaded by distributed loads and/or by concentrated loads if* $crs_{bolt} > 2xh_{post}$*)*

Required area of embedment strength:

$$A_{req} := \frac{F_w}{f_{c.90.d} \cdot k_{c.90}} = 950.259 \cdot mm^2$$

Washer plate edge: $Squ := 35mm$

$$A_{prov.s} := Squ \cdot Squ - 0.25 \cdot \pi (12mm)^2 = 1111.903 \cdot mm^2$$

therefore = "OK"

NOTE: Min. edge distance is 80mm with min. 45mm embedment into brick $20N/mm^2$.

9. Summary:

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* Use **75x200 C24** constructional sawn timber posts at following crs: **2.0m** (to all zones);
* Use **3No. 50x75 C16** constructional sawn timber rails at **760mm** centres max;
* Face material assumed as **18mm FSC Grade Plywood**;
* Use **6mm wood screws 50mm long** for the ply to rail connection at **300mm** centres;
* Use **1No. 6mm wood screws 150mm long** per rail to post connection;
* Posts to be secured to brick wall;
* Timber posts fixed directly to the **front** of kentledge blocks with **3No. M08 Excalibur bolts (or other approved)** with **35x35x6mm thick steel washer** under each bolt
* All timber holes must be **pre-drilled**.

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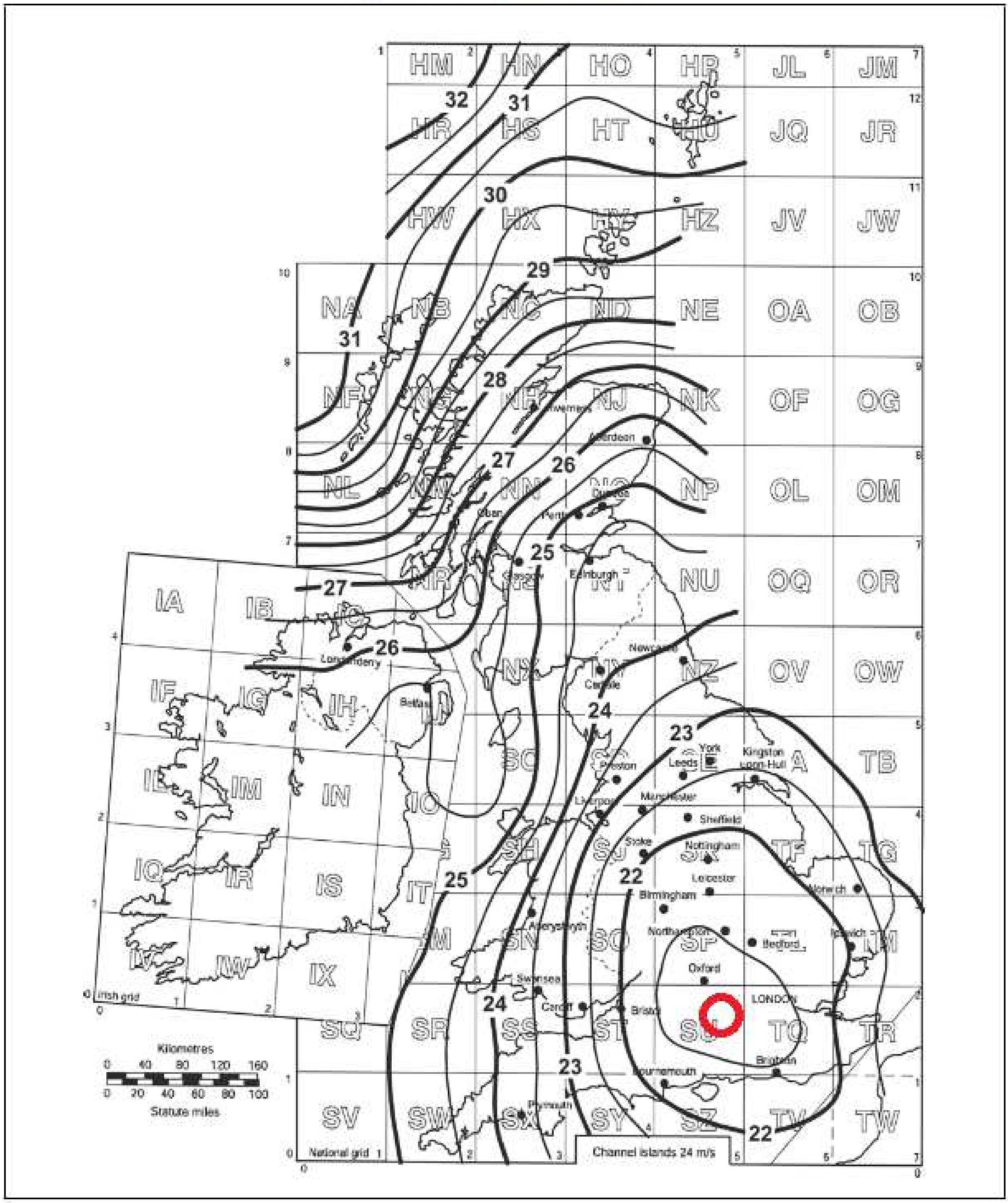
APPENDIX A

Figure NA.1 Value of fundamental basic wind velocity $v_{b,map}$ (m/s) before the altitude correction is applied



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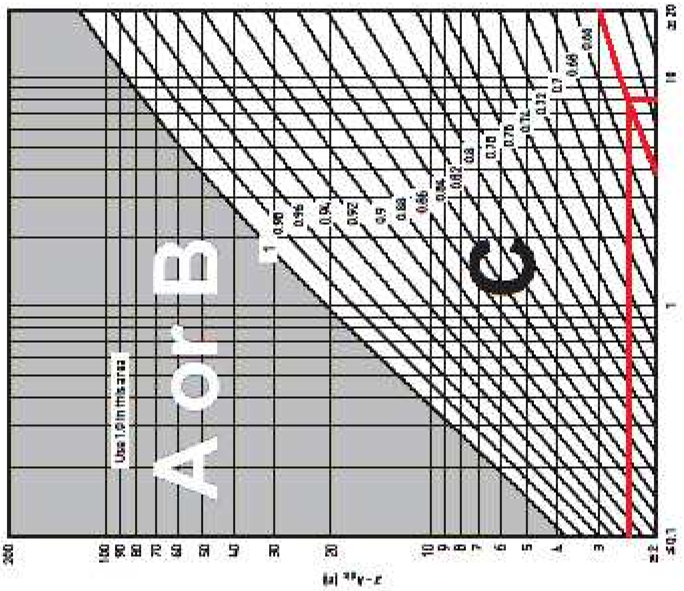
	Date:	13-06-2017

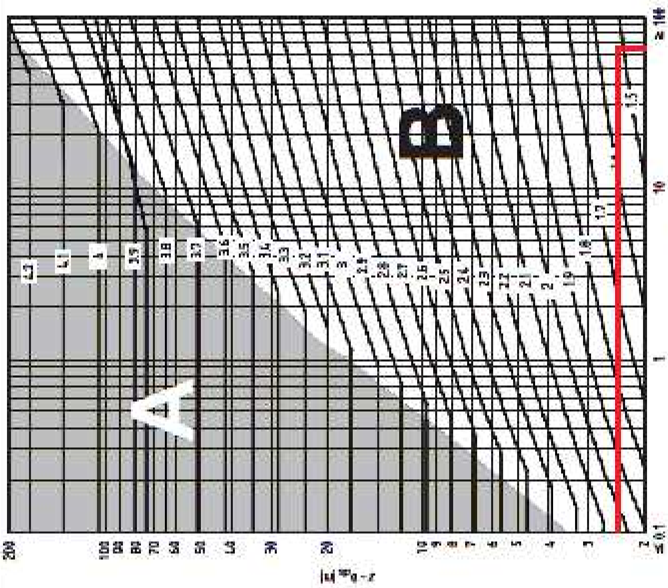
APPENDIX B

Figure NA.9 Values of exposure correction factor $c_{e,T}$ for sites in Town terrain



NOTE 1 The height z is the height at which q_p is sought using Equation NA.3a) or NA.3b).
NOTE 2 Zones A, B and C are indicated for use in Table NA.5.

Figure NA.7 Values of $c_e(z)$



NOTE 1 The height z is the height at which q_p is sought using Equations NA.3a) or NA.3b).
NOTE 2 Zones A and B are indicated for use in Table NA.4.

APPENDIX C

Allowable internal forces
for timber beams
(according to BS 5268-2:2002)

75x200mm C24 timber posts

Dimensions of cross-section: $a = 3 \cdot in$ $b = 8 \cdot in$

Section area: $A_s := a \cdot b = 140.4 \cdot cm^2$

Moment of inertia: $I_y := \frac{a \cdot b^3}{12} = 4448.925 \cdot cm^4$

Section modulus: $W_y := \frac{a \cdot b^2}{6} = 456.3 \cdot cm^3$

Timber_grade = "C24"

Bending stress parallel to grain: $fZ = 7.5 \cdot \frac{N}{mm^2}$

Shear stress parallel to grain (service class 3): $qA = 0.71 \cdot \frac{N}{mm^2}$

Mean modulus of elasticity (service class 3): $E_{0.mean} = 8640 \cdot \frac{N}{mm^2}$

Minimum modulus of elasticity: $E_{min} = 5760 \cdot \frac{N}{mm^2}$

Aplication = "load sharing - hoarding"

Factor converting service classes 1 and 2 strength classes to service class 3 (bending): $K_{2b} := 0.8$

Factor converting service classes 1 and 2 strength classes to service class 3 (shear): $K_{2s} := 0.9$

Duration of load factor: $K_3 = 1.75$

Bearing stress factor: $K_4 := 1.0$

Form factor: $K_6 := 1.0$

Depth factor: $K_7 = 1.046$

Load sharing factor: $K_8 = 1$

PERMISSIBLE STRESSES

Moment of resistance:

$$M_{RdP} := fZ \cdot W_y \cdot K_{2b} \cdot K_3 \cdot K_4 \cdot K_6 \cdot K_7 \cdot K_8 = 5.01 \cdot kN \cdot m$$

Shear load:

$$V_{RdP} := qA \cdot A_s K_{2s} \cdot K_3 \cdot K_4 \cdot K_6 \cdot K_8 = 15.7 \cdot kN$$

50x75mm C16 timber rails

Dimensions of cross-section: $a = 2 \cdot in$ $b = 3 \cdot in$

Section area: $A_s := a \cdot b = 33.84 \cdot cm^2$

Moment of inertia: $I_y := \frac{a \cdot b^3}{12} = 146.189 \cdot cm^4$

Section modulus: $W_y := \frac{a \cdot b^2}{6} = 40.6 \cdot cm^3$

Timber_grade = "C16"

Bending stress parallel to grain: $fZ = 5.3 \cdot \frac{N}{mm^2}$

Shear stress parallel to grain (service class 3): $qA = 0.67 \cdot \frac{N}{mm^2}$

Mean modulus of elasticity (service class 3): $E_{0.mean} = 7040 \cdot \frac{N}{mm^2}$

Minimum modulus of elasticity: $E_{min} = 4640 \cdot \frac{N}{mm^2}$

Aplication = "load sharing - hoarding"

Factor converting service classes 1 and 2 strength classes to service class 3 (bending): $K_{2b} := 0.8$

Factor converting service classes 1 and 2 strength classes to service class 3 (shear): $K_{2s} := 0.9$

Duration of load factor: $K_3 = 1.75$

Bearing stress factor: $K_4 := 1.0$

Form factor: $K_6 := 1.0$

Depth factor: $K_7 = 1.165$

Load sharing factor: $K_8 = 1$

Plywood used: **18mm Finish plywood - sanded (9 veneers)**

Characteristic mean modulus of elasticity in bending - face grain perpendicular to span: $E_{m.ply} := 3350 \frac{N}{mm^2}$

Modification factor for creep deformation and service class (table 38 BS EN 5268-2): $k_{def} := 0.0$

Duration of load and servce class factor for plywood (short and very short term - table 39 BS EN 5268-2): $K_{36} := 1.43$

Grade modulus value: $E_{d.ply} := \frac{E_{m.ply}}{1 + k_{def}} \cdot K_{36} = 4790.5 \cdot \frac{N}{mm^2}$

Area of ply in the face contact with rail: $A_{ply} := 18mm \cdot a = 8.46 \cdot cm^2$

Rail and plywood modulus of elasticity ratio: $\alpha := \frac{E_{0.mean}}{E_{d.ply}} = 1.47$

Moment of inertia of ply section: $I_{y.ply} := \frac{a \cdot (18mm)^3}{12} = 2.284 \cdot cm^4$

Transformed area of the timber component: $A_i := A_s + \frac{A_{ply}}{\alpha} = 39.597 \cdot cm^2$

Distance between centroid of ply section and centroid of rail section: $y_{dist} := \frac{b}{2} + \frac{18mm}{2} = 4.5 \cdot cm$

Distance between centroid of rail section and centroid of transformed timber component: $y_r := \frac{A_{ply}}{\alpha \cdot A_i} \cdot y_{dist} = 6.542 \cdot mm$

Distance between centroid of ply section and centroid of transformed timber component: $y_{ply} := \frac{A_s}{A_i} \cdot y_{dist} = 3.846 \cdot cm$

Distance between centroid of transformed timber component and top fibre of the section: $y_u := y_{ply} + \frac{18mm}{2} = 4.746 \cdot cm$

Distance between centroid of transformed timber component and bottom fibre of the section: $y_d := y_r + \frac{b}{2} = 4.254 \cdot cm$

Moment of inertia of transformed timber component: $I_c := I_y + \frac{I_{y.ply}}{\alpha} \ldots + A_s \cdot y_{dist} \cdot y_r = 247.369 \cdot cm^4$

Section modulus - top fibres: $W_{y.u} := \frac{I_c}{y_u} = 52.124 \cdot cm^3$

Section modulus - bottom fibres: $W_{y.d} := \frac{I_c}{y_d} = 58.147 \cdot cm^3$

Min. section modulus: $W_y := \min(W_{y.u}, W_{y.d}) = 52.1 \cdot cm^3$

Section area: $A_s := A_i = 39.597 \cdot cm^2$

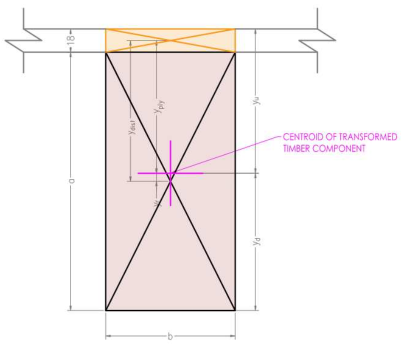
PERMISSIBLE STRESSES

Moment of resistance:

$M_{Rd} := fZ \cdot W_y \cdot K_{2b} \cdot K_3 \cdot K_4 \cdot K_6 \cdot K_7 \cdot K_8 = 0.45 \cdot kN \cdot m$

Shear load:

$V_{Rd} := qA \cdot A_s K_{2s} \cdot K_3 \cdot K_4 \cdot K_6 \cdot K_8 = 4.18 \cdot kN$



geometric properties of transformed timber component

1. Description:

Revision:

CC0 - N/A

Aim:

Provide calculations for 5.0m width access gate secured to steel post embedded into the ground. All set out on the drawing no. ***3417-18-P0.***

Loadings:

This structure has been designed in accordance with the following guidance:

- *BS EN 1991-1-4:2005 - Wind Actions & TG20-13 Wind Guidance*
- *BS 5975:2008 - Code of practice for temp. works procedures and the permissible stress design of falsework*
- *BS 6180:2011 - Table 2*
- *TWf 2012:01 HOARDINGS: A guide to good practice*

2. Loading:

2.1. Minimum notional horizonal load:

The minimum notional horizontal load applied to hoarding is:

$H_z := 0.74 \frac{kN}{m}$, acting at height of: $h_z := 1.2m$ above the base.

2.2. Wind load:

Gate dimnesions:

Gate length: $l := 5m$

total length: $b := l = 5\,m$

bay width: $d := 0.1m$

Gate height: $h := 2.5m$

Site location data:

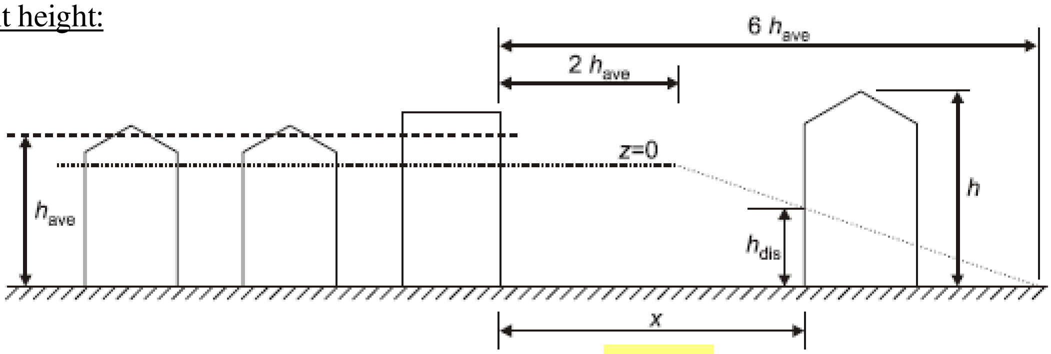
altitude of the site: $A := 60m$

distance to shoreline: $dist_{sh} := 65km$

distance inside town terrain: $dist_{town} := 8km$

Displacement height:

$h_{ave} := 0m$

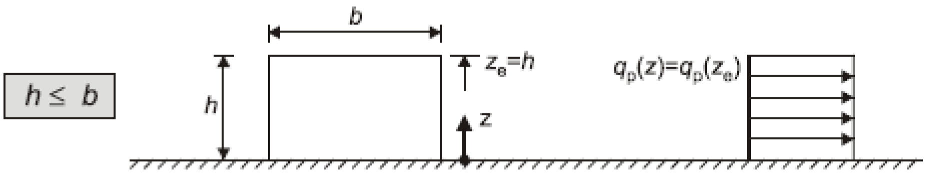


$x := 0m$

$$h_{dis} := \begin{cases} \min(0.8h_{ave}, 0.6 \cdot h) & \text{if } x \le 2 \cdot h_{ave} \\ \min(1.2h_{ave} - 0.2x, 0.6 \cdot h) & \text{if } x > 2h_{ave} \wedge x < 6.h_{ave} \\ 0 & \text{if } x \ge 6h_{ave} \end{cases} = 0m$$

Reference height for Wind Calculation:

$h = 2.5m \quad < \quad b = 5m$



reference height: $z_e := h = 2.5m$

Fundamental value of of basic wind velocity:

fundamental value of basic wind velocity before altitude correction: $v_{b.map} := 21.5 \frac{m}{s}$ *[Figure NA.1]* *(see appendix A for details)*

altitude factor:

$$c_{alt} := \begin{cases} 1 + 0.001 \frac{A}{m} & \text{if } z_e \le 10m \\ 1 + 0.001 \frac{A}{m} \cdot \left(\frac{10m}{z_e}\right)^{0.2} & \text{if } z_e > 10m \end{cases} = 1.06$$

$$v_{b.0} := v_{b.map} \cdot c_{alt} = 22.79 \frac{m}{s}$$

The basic wind velocity:

directional factor: $c_{dir} := 1.0$ *(for simplification)*

season factor: $c_{season} := 1.0$ *(for simplification)*

probability factor: $c_{prob} := 0.83$ *(gate with hoarding up to 2 years)*

$$v_b := c_{prob} \cdot c_{dir} \cdot c_{season} \cdot v_{b.0} = 18.916 \frac{m}{s}$$

Basic velocity pressure:

air density (NA.2.18): $\rho := 1.226 \frac{kg}{m^3}$

$$q_b := \frac{1}{2} \rho \cdot v_b^{\ 2} = 0.219 \cdot kPa$$

Peak Velocity pressure:

Distance upwind to shoreline: $dist_{sh} = 65 \cdot km$

Distance inside town terrain: $dist_{town} = 8 \cdot km$

Reference height - displacement height: $z_e - h_{dis} = 2.5\,m$

exposure factor: $c_e := 1.55$ *[Figure NA.7]* *(see appendix B for details)*

exposure factor for town terrain: $c_{e.T} := 0.64$ *[Figure NA.8]* *(see appendix B for details)*

(for country site terrain = 1.0)

FULL WIND

$$q_p := c_e \cdot c_{e.T} \cdot q_b = 0.218 \cdot kPa$$

WORKING WIND

$$q_{p.work} := 0.2 kPa$$

Wind pressure on surfaces - free-standing wall:

solidity ratio: $\varphi := 1.0$

return corners: $rc := NO$

length to height ratio: $\frac{l}{h} = 2$

Table 7.9 — Recommended pressure coefficients $c_{p,net}$ for free-standing walls and parapets

Solidity	Zone		A	B	C	D
$\varphi = 1$	Without return corners	$\ell/h \leq 3$	2,3	1,4	1,2	1,2
		$\ell/h = 5$	2,9	1,8	1,4	1,2
		$\ell/h \geq 10$	3,4	2,1	1,7	1,2
	with return corners of length $\geq h$ [a]		2,1	1,8	1,4	1,2
$\varphi = 0,8$			1,2	1,2	1,2	1,2

[a] Linear interpolation may be used for return corner lengths between 0,0 and h

Zone A:

NOTE: *Calculations may be neglected (Zone A is only 0.72m wide)*

Zone B:

$c_{pe.net.B} = 1.4$

$W_B := q_p \cdot c_{pe.net.B} = 0.305 \cdot kPa$

$W_{B.work} := q_{p.work} \cdot c_{pe.net.B} = 0.28 \cdot kPa$

zone lengths:

$l_{b.ac} := 2 \cdot h = 5\,m$

$l_b := l_{b.ac} - 0.3 \cdot h = 4.25\,m$

Zone C:

$c_{pe.net.C} = 1.2$

$W_C := q_p \cdot c_{pe.net.C} = 0.261 \cdot kPa$

$W_{C.work} := q_{p.work} \cdot c_{pe.net.C} = 0.24 \cdot kPa$

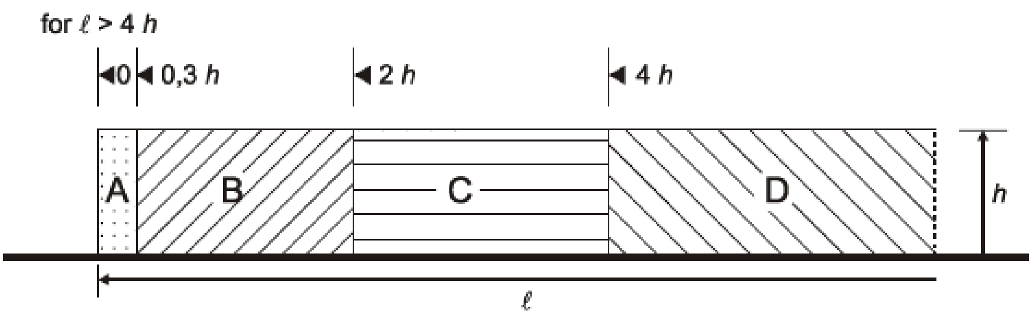
zone lengths:

$l_{c.ac} := 4 \cdot h = 10\,m$

$l_c := l_{c.ac} - l_{b.ac} = 5\,m$

Zone D:

NOTE: *Calculations may be neglected (in the worst case scenario zone D does not include the length of the gate)*



	CALCULATION SHEET		
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		Prepared by:	MAT
	Customer: ***48 SHOOT UP HILL LTD***	*Checked by:*	TS
		Date:	13-06-2017

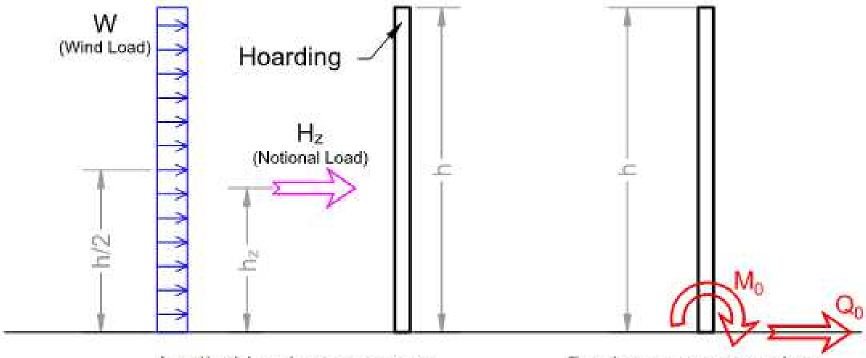
3. Posts design:

Perm. BM and SF:

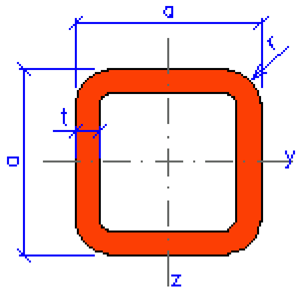
Post used: **SHS 100x100x5 S355**

$M_{Rd} := 23.572\text{kNm}$ $\quad Q_{Rd} := 191.637\text{kN}$

(for details see app. C)



Applied loads on system   Design representation



Profile cross section

Post cantilever length: $p := h = 2.5\,m$

Notional load lever arm: $p_z := \max(p + h_z - h, 0m) = 1.2\,m$

Gate leaf dimensions:

$h = 2.5\,m$ - *gate height*

$0.5l = 2.5\,m$ - *leaf length*

$W_{gate} := 300kg$ - *gate weight (ONE LEAF)*

Two load cases:

LC1: Full Wind

LC2: Working Wind + Lateral Load

NOTE: Blocks also stabilise an additional 2.0m wide hoarding (for ZONE D spacing from hoarding calculations).

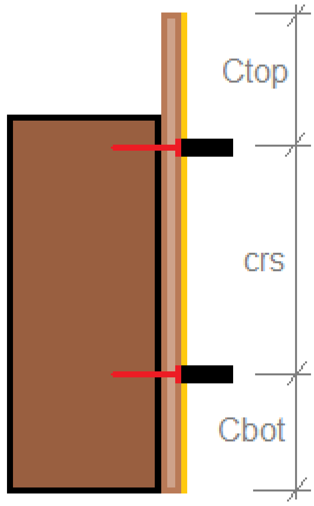
$b_h := \frac{2.0m}{2} = 1\,m$

Connectors information:

$c_{top} := 300mm$ - *bolt to upper box edge distance*

$c_{bot} := 300mm$ - *bolt to lower box edge distance*

$crs_{conn} := h - c_{top} - c_{bot} = 1.9\,m$ - *bolt centres*



Max. bending moment in post:

$$M_0 := \max\left[\begin{pmatrix}0.51 \dots \\ + b_h\end{pmatrix}\cdot h \cdot W_B \cdot \frac{h}{2}, \left(0.51 + b_h\right)\cdot h \cdot W_{B.work} \cdot \frac{h}{2} \dots + \left(0.51 + b_h\right)\cdot H_z \cdot h_z\right] = 6.17\cdot kNm$$

$$M_{90} := W_{gate} \cdot g \cdot 0.251 + 0.9kN \cdot 0.51 = 5.927\cdot kNm$$

bending = "OK"

NOTE: 0.9kN as a load from worker on leaf.

Max. shear force in post:

$$Q_0 := \left(0.51 + b_h\right)\cdot \max\left(W_B \cdot p, W_{B.work} \cdot p + H_z\right) = 5.04\cdot kN$$

$$Q_{90} := \frac{M_{90}}{crs_{conn}} = 3.12\cdot kN$$

shear = "OK"

<u>Ground resistance moment:</u>

Ground factor (for <u>average</u> quality of the ground): $G := 390 \frac{kN}{m^2}$

Minimum effective width of concreted foundation: $D := 0.40m$

Planting depth of the post from ground level: $P := 1.0m$

Factor of safety for destabilizing variable actions: $\gamma_F := 1.5$

$$M_g := \frac{G \cdot D \cdot P^3}{10m} = 15.6\cdot kNm$$

<u>Max. overturning moment about fulcrum point:</u>

$$M_{O.0} := \left[M_0 + \left(0.707 \cdot Q_0 \cdot P\right)\right]\cdot \gamma_F = 14.601\cdot kNm \quad < \quad M_g = 15.6\cdot kNm$$

therefore = "OK"

$$M_{O.90} := \left[M_{90} + \left(0.707 \cdot Q_{90} \cdot P\right)\right]\cdot \gamma_F = 12.2\cdot kNm \quad < \quad M_g = 15.6\cdot kNm$$

therefore = "OK"

4. Connection of hinger to gate

Zone A:

$W_A := q_p \cdot c_{pe.net.A} = 0.5 \cdot kPa$

$W_{A.work} := q_{p.work} \cdot c_{pe.net.A} = 0.46 \cdot kPa$

zone length:

$l_a := 0.3 \cdot h = 0.75\,m$

Max. load on connection in wind zone A:

$$q_{close} := 0.5 \cdot h \cdot \max\left(W_A \cdot 0.51, W_{A.work} \cdot 0.51 + H_z\right) = 2.362 \cdot kN$$

Max. load on connection in case with open gates:

$$q_{open} := Q_{90} = 3.12\,kN$$

Basic withdrawal load per mm of penetration:

$F_t := 18.2 \frac{N}{mm}$

Connection used: 6mm wood screws, 50mm long

Assumed no. of screws: $n := 5$

Point side penetration: $e := 50mm - 10mm = 40 \cdot mm$

Basic single shear lateral load [BS 5268-2:2002, table 66]:

$F_s := 765N$

Design factors:

$K_{52} := 1.25$ (very short term loading) $K_{53} := 0.7$ (Class 3) $K_{54} := 1$ (for no. of screws < 10)

Permissible load per metre:

$$Q_{t.Rd} := n \cdot e \cdot F_t \cdot K_{52} \cdot K_{53} \cdot K_{54} = 3.19 \cdot kN \quad > \quad \max\left(q_{close}, q_{open}\right) = 3.12 \cdot kN$$

uplifting = "OK"

$$Q_{s.Rd} := n \cdot F_s \cdot K_{52} \cdot K_{53} \cdot K_{54} = 3.35 \cdot kN \quad > \quad q_{open} = 3.12 \cdot kN$$

shear = "OK"

5. Welded connection of steel hinge to post:

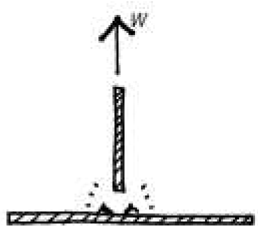
Weld information:

Weld length: $W_{Lg} := 50mm$

Weld leg length: $s := 6mm$

Throat thickness: $a := 0.7s = 4.2 \cdot mm$

Transverse capacity: $P_L := 1.155kN \cdot mm^{-1}$



NOTE: Calculations based on values S275, ρw = 220 N/mm^2 and K=1.25.

Max. withdrawal force on connection:

$$W := q_{open} = 3.12\,kN$$

Permissible load (lower weld):

$$W_{Rd} := W_{Lg} \cdot P_L = 57.75 \cdot kN \quad > \quad W = 3.12 \cdot kN$$

therefore = "OK"

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	Customer: ***48 SHOOT UP HILL LTD***	Checked by:	TS
		Date:	13-06-2017

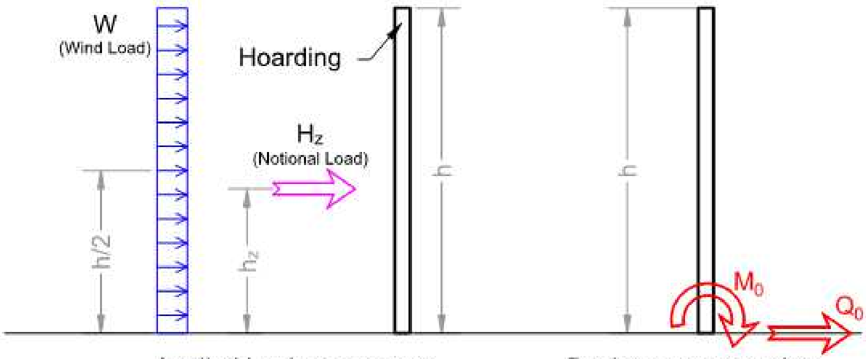
6. Timber posts design (alternative):

Perm. BM and SF:

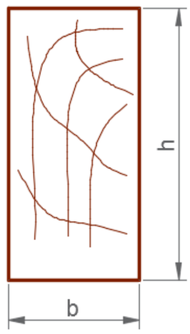
Post used: **Timber 150x150mm C24**

$M_{Rd} := 6.374kNm$ $\quad Q_{Rd} := 25.16kN$

(for details see app. D)



Applied loads on system   Design representation



Profile cross section

Post cantilever length: $p := h = 2.5\,m$

Notional load lever arm: $p_z := \max\left(p + h_z - h, 0m\right) = 1.2\,m$

Gate leaf dimensions:

$h = 2.5\,m$ - *gate height*

$0.5l = 2.5\,m$ - *leaf length*

$W_{gate} = 300\,kg$ - *gate weight (ONE LEAF)*

Two load cases:

LC1: Full Wind

LC2: Working Wind + Lateral Load

NOTE: Blocks also stabilise an additional 2.0m wide hoarding (for ZONE D spacing from hoarding calculations).

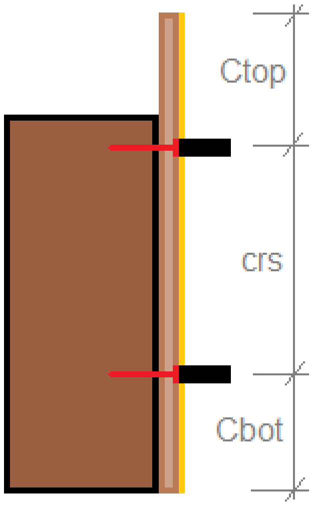
$b_h = 1\,m$

Connectors information:

$c_{top} = 300\,mm$ - *bolt to upper box edge distance*

$c_{bot} = 300\,mm$ - *bolt to lower box edge distance*

$crs_{conn} := h - c_{top} - c_{bot} = 1.9\,m$ - *bolt centres*



Max. bending moment in post:

$$M_0 := \max\left[\left(0.5l + b_h\right)\cdot h\cdot W_B\cdot\frac{h}{2}, \left(0.5l + b_h\right)\cdot h\cdot W_{B.work}\cdot\frac{h}{2} + \left(0.5l + b_h\right)\cdot H_z\cdot h_z\right] = 6.17\cdot kNm$$

$$M_{90} := W_{gate}\cdot g\cdot 0.25l + 0.9kN\cdot 0.5l = 5.927\cdot kNm$$

bending = "OK"

NOTE: 0.9kN as a load from worker on leaf.

Max. shear force in post:

$$Q_0 := \left(0.5l + b_h\right)\cdot\max\left(W_B\cdot p, W_{B.work}\cdot p + H_z\right) = 5.04\cdot kN$$

$$Q_{90} := \frac{M_{90}}{crs_{conn}} = 3.12\cdot kN$$

shear = "OK"

7. Connectionon of steel hinge to post:

Zone A:

$$W_A := q_p\cdot c_{pe.net.A} = 0.5\cdot kPa$$

$$W_{A.work} := q_{p.work}\cdot c_{pe.net.A} = 0.46\cdot kPa$$

zone length:

$$l_a := 0.3\cdot h = 0.75\,m$$

Max. load on connection in wind zone A:

$$q_{close} := 0.5\cdot h\cdot\max\left(W_A\cdot 0.5l, W_{A.work}\cdot 0.5l + H_z\right) = 2.362\cdot kN$$

Max. load on connection in case with open gates:

$$q_{open} := Q_{90} = 3.12\,kN$$

Basic withdrawal load per mm of penetration:

$$F_t := 21.1\frac{N}{mm}$$

Connection used: 6mm wood screws, 50mm long

Assumed no. of screws: $n := 5$

Point side penetration: $e := 50mm - 10mm = 40\cdot mm$

Basic single shear lateral load [BS 5268-2:2002, table 66]:

$$F_s := 826N$$

Design factors:

$K_{52} := 1.25$ (very short term loading) $K_{53} := 0.7$ (Class 3) $K_{54} := 1$ (for no. of screws < 10)

Permissible load per metre:

$$Q_{t.Rd} := n\cdot e\cdot F_t\cdot K_{52}\cdot K_{53}\cdot K_{54} = 3.69\cdot kN \quad > \quad \max\left(q_{close}, q_{open}\right) = 3.12\cdot kN$$

uplifting = "OK"

$$Q_{s.Rd} := n\cdot F_s\cdot K_{52}\cdot K_{53}\cdot K_{54} = 3.61\cdot kN \quad > \quad q_{open} = 3.12\cdot kN$$

shear = "OK"

8. Summary:

****

* **2.5m high gate** to be secured to **SHS 100x100x5mm S355** steel post (or to **timber post 150x150mm C24** - as alternative (150mm - finished size of a timber)
* Posts also stabilise adjacent hoarding.
* The gates were covered in **ply**.
* Max. weigh of the gate to be **300kg (one leaf).**
* Posts to be embedded into the ground in **400mm dia. hole, 1.00m deep** and infilled with concrete.
* Gate fixed to posts with steel hinge (using **5No. 6mm wood screws, 50mm long** (per connection), hinge fixed to steel post on **6mm welded** connection (for timber post connection use **5No. 6mm wood screws, 50mm long** (per one hinge).

****

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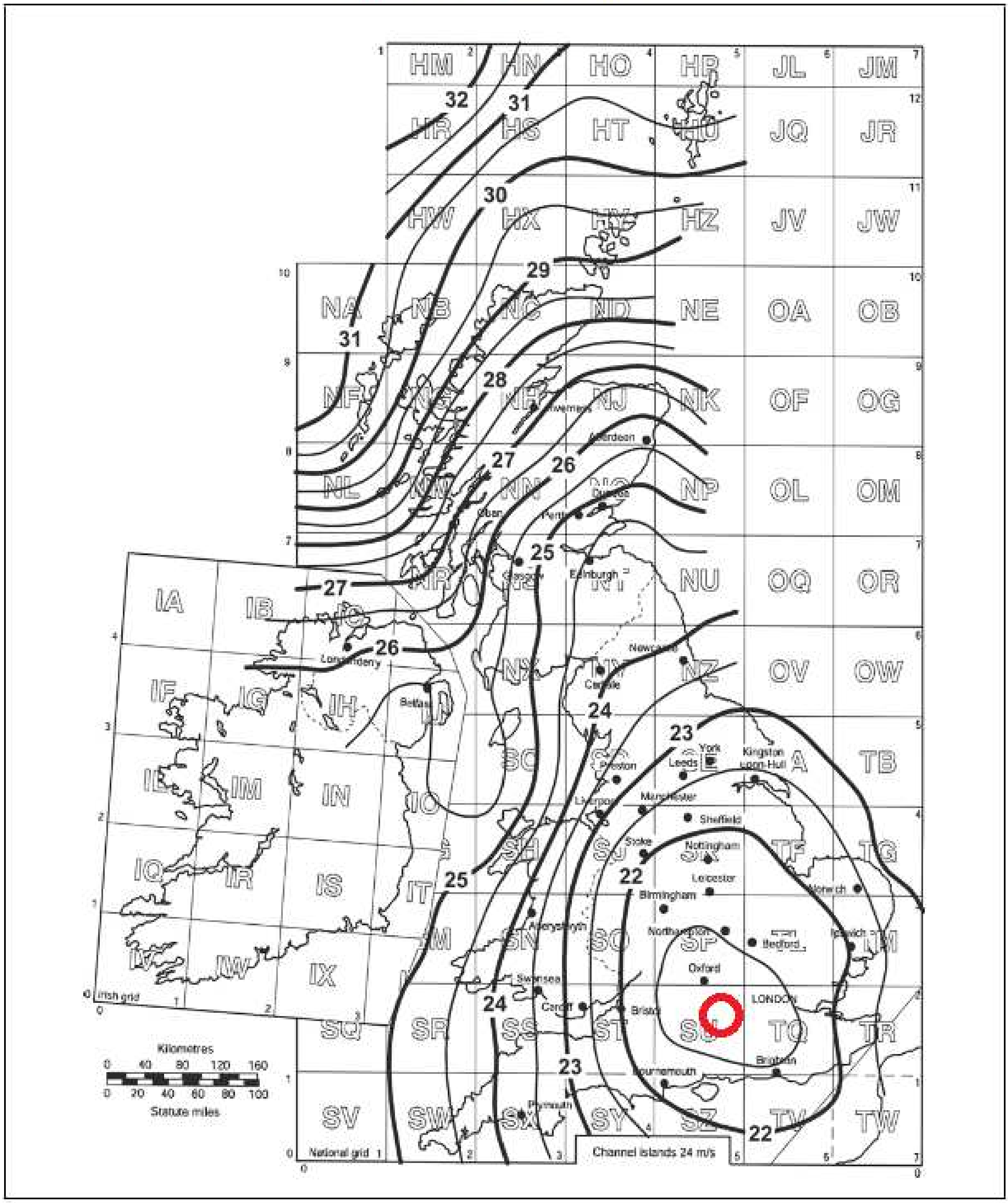
		Prepared by:	MAT
	Customer: ***48 SHOOT UP HILL LTD***	*Checked by:*	TS
		Date:	13-06-2017

APPENDIX A

Figure NA.1 Value of fundamental basic wind velocity $v_{b,map}$ (m/s) before the altitude correction is applied



IDH INDEPENDENT DESIGN HOUSE LTD	CALCULATION SHEET	Job No	3417-18
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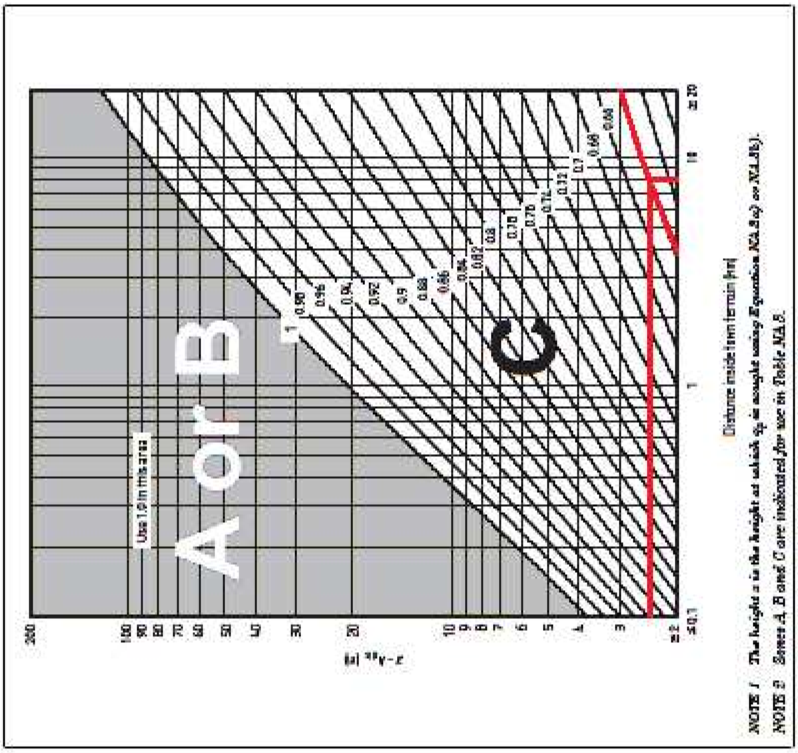
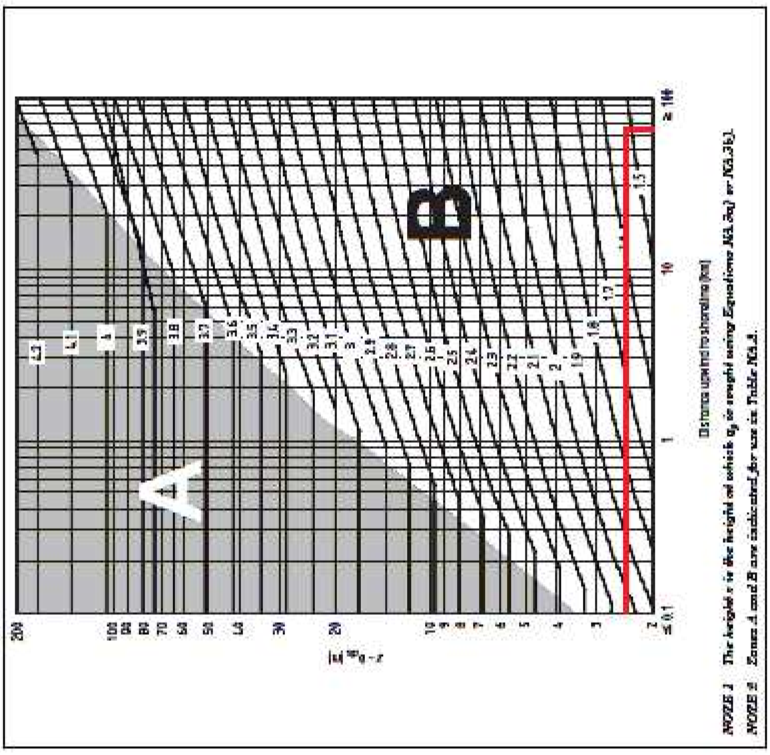
	Title: **HOARDING**	Sheet:	43
		Prepared by:	MAT
	Customer: **48 SHOOT UP HILL LTD**	Checked by:	TS
		Date:	13-06-2017

APPENDIX B





APPENDIX C

Allowable internal forces for steel column

(according to BS 1993-1-1:2006)

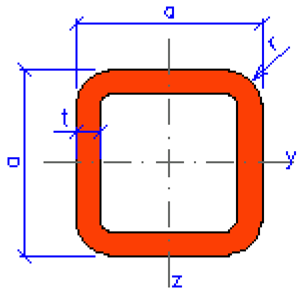
Profile: SHS 100x100x5 S355

Section dimensions:

$a := 10cm$

$t := 0.5cm$

$r := 0.75cm$



Profile cross section

Section properties:

$A_s := 18.7cm^2$ — *sectional area*

$I_y := 279cm^4$ — *second moment of area (axis Y-Y)*

$I_z := I_y = 279 \cdot cm^4$ — *second moment of area (axis Z-Z)*

$i_y := \sqrt{\frac{I_y}{A_s}} = 3.86 \cdot cm$ — *radius of gyration (axis Y-Y)*

$i_z := \sqrt{\frac{I_z}{A_s}} = 3.86 \cdot cm$ — *radius of gyration (axis Z-Z)*

$W_{el.y} := 55.9cm^3$ — *elastic modulus (axis Y-Y)*

$W_{el.z} := W_{el.y} = 55.9 \cdot cm^3$ — *elastic modulus (axis Z-Z)*

$W_{pl.y} := 66.4cm^3$ — *plastic modulus (axis Y-Y)*

$W_{pl.z} := W_{pl.y} = 66.4 \cdot cm^3$ — *plastic modulus (axis Z-Z)*

Steel properties: **S355 steel** *(Table 3.1 BS EN 1993-1-1)*

$f_y := 355MPa$ — *nominal yield strength*

$E_s := 210GPa$ — *modulus of elasticity*

Classification of cross section (Table 5.2 BS EN 1993-1-1)

$$\varepsilon := \sqrt{\frac{235MPa}{f_y}} = 0.814$$

-WEB

$c := a - 2t - 2r = 75 \cdot mm$

$t = 5 \cdot mm$

$class := Cl_{w.b} = 1$

Bending: $Cl_{w.b} := \begin{cases} 1 & \text{if } \frac{c}{t} \le 72\varepsilon \\ 2 & \text{if } \frac{c}{t} \le 83\varepsilon \wedge \frac{c}{t} > 72\varepsilon \\ 3 & \text{if } \frac{c}{t} \le 124\varepsilon \wedge \frac{c}{t} > 83\varepsilon \\ 4 & \text{otherwise} \end{cases} = 1$

Bending

Partial factors: (Section 6.1 BS EN 1993-1-1)

$\gamma_{M0} := 1.00$ *-resistance of cross-sections whatever the class is*

Design shear resistance

$$M_{c.Rd} := \frac{W_{pl.y} \cdot f_y}{\gamma_{M0}} = 23.572 \cdot kNm$$

Shear

Shear area:

$$A_v := \frac{A_s \cdot a}{2a} = 935 \cdot mm^2$$

$$V_{pl.Rd} := \frac{A_v \cdot \left(\frac{f_y}{\sqrt{3}}\right)}{\gamma_{M0}} = 191.637 \cdot kN$$

Design shear resistance

$$V_{c.Rd} := \begin{cases} V_{pl.Rd} & \text{if } class = 1 \vee class = 2 \\ \text{"stress analysis required"} & \text{if } class = 3 \end{cases} = 191.637 \cdot kN$$

PERMISSIBLE STRESSES

Moment of resistance: $M_{c.Rd} = 23.572 \cdot kNm$

Shear load: $V_{c.Rd} = 191.637 kN$

APPENDIX D

Allowable internal forces for timber beams *(according to BS 5268-2:2002)*

Profile: Timber 150x150mm C24

Dimensions of cross-section: $a = 6 \cdot in$ $b = 6 \cdot in$

Section area: $A_s := a \cdot b = 225 \cdot cm^2$

Moment of inertia: $I_y := \frac{a \cdot b^3}{12} = 4218.75 \cdot cm^4$

Section modulus: $W_y := \frac{a \cdot b^2}{6} = 562.5 \cdot cm^3$

Timber_grade = "C24"

Bending stress parallel to grain: $fZ = 7.5 \cdot \frac{N}{mm^2}$

Shear stress parallel to grain (service class 3): $qA = 0.71 \cdot \frac{N}{mm^2}$

Mean modulus of elasticity (service class 3): $E_{0.mean} = 8640 \cdot \frac{N}{mm^2}$

Minimum modulus of elasticity: $E_{min} = 5760 \cdot \frac{N}{mm^2}$

Aplication = "load sharing - hoarding"

Factor converting service classes 1 and 2 strength classes to service class 3 (bending): $K_{2b} := 0.8$

Factor converting service classes 1 and 2 strength classes to service class 3 (shear): $K_{2s} := 0.9$

Duration of load factor: $K_3 = 1.75$

Bearing stress factor: $K_4 := 1.0$

Form factor: $K_6 := 1.0$

Depth factor: $K_7 = 1.079$

Load sharing factor: $K_8 = 1$

PERMISSIBLE STRESSES

Moment of resistance: $M_{RdP} := fZ \cdot W_y \cdot K_{2b} \cdot K_3 \cdot K_4 \cdot K_6 \cdot K_7 \cdot K_8 = 6.374 \cdot kN \cdot m$

Shear load: $V_{RdP} := qA \cdot A_s K_{2s} \cdot K_3 \cdot K_4 \cdot K_6 \cdot K_8 = 25.16 \cdot kN$