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BALLAST APPRAISAL

4 WILD COURT LONDON WC2B 4AU

CALCULATIONS CARRIED OUT IN ACCORDANCE WITH MCS STANDARDS

ISSUE No.	-				
DATE	08/10/2019				
PREPARED BY	BMcG				
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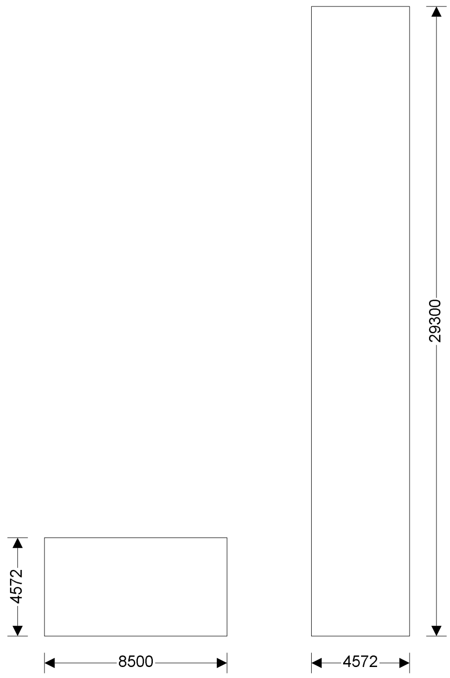
WIND LOADING

In accordance with EN1991-1-4:2005+A1:2010 and the UK national annex

Tedds calculation version 3.0.23



Plan Elevation

Building data

Type of roof;	Flat
Length of building;	L = **8500** mm
Width of building;	W = **4572** mm
Height to eaves;	H = **29300** mm
Eaves type;	Sharp
Total height;	h = **29300** mm

Basic values

Location;	London
Wind speed velocity (FigureNA.1);	$v_{b,map}$ = **21.4** m/s
Distance to shore;	L_{shore} = **38.10** km
Altitude above sea level;	A_{alt} = **42.0**m
Altitude factor;	$c_{alt} = A_{alt}/1\text{m} \times 0.001 + 1 =$ **1.042**
Fundamental basic wind velocity;	$v_{b,0} = v_{b,map} \times c_{alt} =$ **22.3** m/s
Direction factor;	c_{dir} = **1.00**
Season factor;	c_{season} = **1.00**
Shape parameter K;	K = **0.2**
Exponent n;	n = **0.5**
Air density;	ρ = **1.226** kg/m^3
Probability factor;	$c_{prob} = [(1 - K \times \ln(-\ln(1-p)))/(1 - K \times \ln(-\ln(0.98)))]^n =$ **1.00**

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Basic wind velocity (Exp. 4.1); $v_b = c_{dir} \times c_{season} \times v_{b,0} \times c_{prob}$ = **22.3** m/s

Reference mean velocity pressure; $q_b = 0.5 \times \rho \times v_b^2$ = **0.305** kN/m²

Orography

Orography factor not significant; c_o = 1.0

Terrain category; Town

Displacement height (sheltering effect excluded); h_{dis} = 0mm

The velocity pressure for the windward face of the building with a 0 degree wind is to be considered as 3 parts as the height h is greater than 2b (cl.7.2.2)

The velocity pressure for the windward face of the building with a 90 degree wind is to be considered as 3 parts as the height h is greater than 2b (cl.7.2.2)

Peak velocity pressure - windward wall (lower part) - Wind 0 deg

Reference height (at which q is sought); z = **8500**mm

Displacement height (sheltering effects excluded); h_{dis} = **0** mm

Exposure factor (Figure NA.7); c_e = **2.28**

Exposure correction factor (Figure NA.8); $c_{e,T}$ = **0.81**

Peak velocity pressure; $q_p = c_e \times c_{e,T} \times q_b$ = **0.56** kN/m²

Structural factor

Structural damping; δ_s = **0.100**

Height of element; h_{part} = **8500** mm

Size factor (Table NA.3); c_s = **0.869**

Dynamic factor (Figure NA.9); c_d = **1.054**

Structural factor; $c_sc_d = c_s \times c_d$ = **0.916**

Peak velocity pressure - windward wall, (middle part) - Wind 0 deg

Reference height (at which q is sought); z = **20800**mm

Displacement height (sheltering effects excluded); h_{dis} = **0** mm

Exposure factor (Figure NA.7); c_e = **2.88**

Exposure correction factor (Figure NA.8); $c_{e,T}$ = **0.90**

Peak velocity pressure; $q_p = c_e \times c_{e,T} \times q_b$ = **0.79** kN/m²

Structural factor

Structural damping; δ_s = **0.100**

Height of element; h_{part} = **12300** mm

Size factor (Table NA.3); c_s = **0.884**

Dynamic factor (Figure NA.9); c_d = **1.054**

Structural factor; $c_sc_d = c_s \times c_d$ = **0.932**

Peak velocity pressure - windward wall (upper part), other walls and roof - Wind 0 deg

Reference height (at which q is sought); z = **29300**mm

Displacement height (sheltering effects excluded); h_{dis} = **0** mm

Exposure factor (Figure NA.7); c_e = **3.11**

Exposure correction factor (Figure NA.8); $c_{e,T}$ = **0.93**

Peak velocity pressure; $q_p = c_e \times c_{e,T} \times q_b$ = **0.89** kN/m²

Structural factor

Structural damping; δ_s = **0.100**

Height of element; h_{part} = **8500** mm

Size factor (Table NA.3); c_s = **0.908**

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Dynamic factor (Figure NA.9);	c_d = **1.054**
Structural factor;	$c_sc_d = c_s \times c_d$ = **0.957**

Structural factor

Structural damping;	δ_s = **0.100**
Height of element;	h_{part} = **29300** mm
Size factor (Table NA.3);	c_s = **0.863**
Dynamic factor (Figure NA.9);	c_d = **1.054**
Structural factor;	$c_sc_d = c_s \times c_d$ = **0.910**

Peak velocity pressure - windward wall (lower part) - Wind 90 deg

Reference height (at which q is sought);	z = **4572**mm
Displacement height (sheltering effects excluded);	h_{dis} = **0** mm
Exposure factor (Figure NA.7);	c_e = **1.90**
Exposure correction factor (Figure NA.8);	$c_{e,T}$ = **0.74**
Peak velocity pressure;	$q_p = c_e \times c_{e,T} \times q_b$ = **0.43** kN/m^2

Structural factor

Structural damping;	δ_s = **0.100**
Height of element;	h_{part} = **4572** mm
Size factor (Table NA.3);	c_s = **0.901**
Dynamic factor (Figure NA.9);	c_d = **1.075**
Structural factor;	$c_sc_d = c_s \times c_d$ = **0.968**

Peak velocity pressure - windward wall, (middle part) - Wind 90 deg

Reference height (at which q is sought);	z = **24728**mm
Displacement height (sheltering effects excluded);	h_{dis} = **0** mm
Exposure factor (Figure NA.7);	c_e = **3.00**
Exposure correction factor (Figure NA.8);	$c_{e,T}$ = **0.92**
Peak velocity pressure;	$q_p = c_e \times c_{e,T} \times q_b$ = **0.84** kN/m^2

Structural factor

Structural damping;	δ_s = **0.100**
Height of element;	h_{part} = **20156** mm
Size factor (Table NA.3);	c_s = **0.881**
Dynamic factor (Figure NA.9);	c_d = **1.075**
Structural factor;	$c_sc_d = c_s \times c_d$ = **0.947**

Peak velocity pressure - windward wall (upper part), other walls and roof - Wind 90 deg

Reference height (at which q is sought);	z = **29300**mm
Displacement height (sheltering effects excluded);	h_{dis} = **0** mm
Exposure factor (Figure NA.7);	c_e = **3.11**
Exposure correction factor (Figure NA.8);	$c_{e,T}$ = **0.93**
Peak velocity pressure;	$q_p = c_e \times c_{e,T} \times q_b$ = **0.89** kN/m^2

Structural factor

Structural damping;	δ_s = **0.100**
Height of element;	h_{part} = **4572** mm
Size factor (Table NA.3);	c_s = **0.941**
Dynamic factor (Figure NA.9);	c_d = **1.075**
Structural factor;	$c_sc_d = c_s \times c_d$ = **1.011**

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Structural factor

Structural damping; δ_s = **0.100**

Height of element; h_{part} = **29300** mm

Size factor (Table NA.3); c_s = **0.871**

Dynamic factor (Figure NA.9); c_d = **1.075**

Structural factor; $c_sc_d = c_s \times c_d$ = **0.936**

Peak velocity pressure for internal pressure

Peak velocity pressure – internal (as roof press.); $q_{p,i}$ = **0.89** kN/m^2

Pressures and forces

Net pressure; $p = c_sc_d \times q_p \times c_{pe} - q_{p,i} \times c_{pi}$;

Net force; $F_w = p_w \times A_{ref}$;

Roof load case 1 - Wind 0, c_{pi} 0.20, -c_{pe}

Zone	Ext pressure coefficient c_{pe}	Peak velocity pressure q_p, (kN/m^2)	Net pressure p (kN/m^2)	Area A_{ref} (m^2)	Net force F_w (kN)
F (-ve)	-2.00	0.89	-1.79	3.61	-6.47
G (-ve)	-1.40	0.89	-1.31	3.61	-4.72
H (-ve)	-0.70	0.89	-0.74	28.90	-21.46
I (-ve)	-0.20	0.89	-0.34	2.74	-0.93

Total vertical net force; $F_{w,v}$ = **-33.58** kN

Total horizontal net force; $F_{w,h}$ = **0.00** kN

Walls load case 1 - Wind 0, c_{pi} 0.20, -c_{pe}

Zone	Ext pressure coefficient c_{pe}	Peak velocity pressure q_p, (kN/m^2)	Net pressure p (kN/m^2)	Area A_{ref} (m^2)	Net force F_w (kN)
A	-1.20	0.89	-1.15	49.81	-57.09
B	-0.80	0.89	-0.82	84.15	-69.28
D_b	0.80	0.56	0.24	72.25	17.00
D_m	0.80	0.79	0.41	104.55	43.11
D_u	0.80	0.89	0.50	72.25	36.27
E	-0.70	0.89	-0.74	249.05	-184.93

Overall loading

Equiv leeward net force for upper section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wu}$ = **-53.6** kN

Net windward force for upper section; $F_w = F_{w,wu}$ = **36.3** kN

Lack of correlation (cl.7.2.2(3) – Note); f_{corr} = **1.00**; as h/W is 6.409

Overall loading upper section; $F_{w,u} = f_{corr} \times (F_w - F_l + F_{w,h})$ = **89.9** kN

Equiv leeward net force for middle section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wm}$ = **-77.6** kN

Net windward force for middle section; $F_w = F_{w,wm}$ = **43.1** kN

Lack of correlation (cl.7.2.2(3) – Note); f_{corr} = **1.00**; as h/W is 6.409

Overall loading middle section; $F_{w,m} = f_{corr} \times (F_w - F_l)$ = **120.7** kN

Equiv leeward net force for bottom section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wb}$ = **-53.6** kN

Net windward force for bottom section; $F_w = F_{w,wb}$ = **17.0** kN

Lack of correlation (cl.7.2.2(3) – Note); f_{corr} = **1.00**; as h/W is 6.409

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Overall loading bottom section; $F_{w,b} = f_{corr} \times (F_w - F_l) =$ **70.7** kN

Roof load case 2 - Wind 0, c_{pi} -0.3, +c_{pe}

Zone	Ext pressure coefficient c_{pe}	Peak velocity pressure q_p, (kN/m^2)	Net pressure p (kN/m^2)	Area A_{ref} (m^2)	Net force F_w (kN)
F (+ve)	-2.00	0.89	-1.35	3.61	-4.87
G (+ve)	-1.40	0.89	-0.86	3.61	-3.12
H (+ve)	-0.70	0.89	-0.30	28.90	-8.64
I (+ve)	0.20	0.89	0.43	2.74	1.17

Total vertical net force; $F_{w,v} =$ **-15.46** kN

Total horizontal net force; $F_{w,h} =$ **0.00** kN

Walls load case 2 - Wind 0, c_{pi} -0.3, +c_{pe}

Zone	Ext pressure coefficient c_{pe}	Peak velocity pressure q_p, (kN/m^2)	Net pressure p (kN/m^2)	Area A_{ref} (m^2)	Net force F_w (kN)
A	-1.20	0.89	-0.70	49.81	-34.99
B	-0.80	0.89	-0.38	84.15	-31.95
D_b	0.80	0.56	0.68	72.25	49.06
D_m	0.80	0.79	0.86	104.55	89.49
D_u	0.80	0.89	0.95	72.25	68.32
E	-0.70	0.89	-0.30	249.05	-74.44

Overall loading

Equiv leeward net force for upper section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wu} =$ **-21.6** kN

Net windward force for upper section; $F_w = F_{w,wu} =$ **68.3** kN

Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} =$ **1.00**; as h/W is 6.409

Overall loading upper section; $F_{w,u} = f_{corr} \times (F_w - F_l + F_{w,h}) =$ **89.9** kN

Equiv leeward net force for middle section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wm} =$ **-31.3** kN

Net windward force for middle section; $F_w = F_{w,wm} =$ **89.5** kN

Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} =$ **1.00**; as h/W is 6.409

Overall loading middle section; $F_{w,m} = f_{corr} \times (F_w - F_l) =$ **120.7** kN

Equiv leeward net force for bottom section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wb} =$ **-21.6** kN

Net windward force for bottom section; $F_w = F_{w,wb} =$ **49.1** kN

Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} =$ **1.00**; as h/W is 6.409

Overall loading bottom section; $F_{w,b} = f_{corr} \times (F_w - F_l) =$ **70.7** kN

Roof load case 3 - Wind 90, c_{pi} 0.20, -c_{pe}

Zone	Ext pressure coefficient c_{pe}	Peak velocity pressure q_p, (kN/m^2)	Net pressure p (kN/m^2)	Area A_{ref} (m^2)	Net force F_w (kN)
F (-ve)	-2.00	0.89	-1.84	1.05	-1.92
G (-ve)	-1.40	0.89	-1.34	1.05	-1.40
H (-ve)	-0.70	0.89	-0.76	8.36	-6.34
I (-ve)	-0.20	0.89	-0.34	28.41	-9.76

Total vertical net force; $F_{w,v}$ = **-19.42** kN

Total horizontal net force; $F_{w,h}$ = **0.00** kN

Walls load case 3 - Wind 90, c_{pi} 0.20, $-c_{pe}$

Zone	Ext pressure coefficient c_{pe}	Peak velocity pressure q_p, (kN/m²)	Net pressure p (kN/m²)	Area A_{ref} (m²)	Net force F_w (kN)
A	-1.20	0.89	-1.17	26.79	-31.45
B	-0.80	0.89	-0.84	107.17	-90.20
C	-0.50	0.89	-0.59	115.09	-68.20
D_b	0.80	0.43	0.15	20.90	3.22
D_m	0.80	0.84	0.46	92.15	42.22
D_u	0.80	0.89	0.54	20.90	11.30
E	-0.62	0.89	-0.69	133.96	-92.99

Overall loading

Equiv leeward net force for upper section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wu}$ = **-14.5** kN

Net windward force for upper section; $F_w = F_{w,wu}$ = **11.3** kN

Lack of correlation (cl.7.2.2(3) – Note); f_{corr} = **0.94**; as h/L is 3.447

Overall loading upper section; $F_{w,u} = f_{corr} \times (F_w - F_l + F_{w,h})$ = **24.3** kN

Equiv leeward net force for middle section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wm}$ = **-64.0** kN

Net windward force for middle section; $F_w = F_{w,wm}$ = **42.2** kN

Lack of correlation (cl.7.2.2(3) – Note); f_{corr} = **0.94**; as h/L is 3.447

Overall loading middle section; $F_{w,m} = f_{corr} \times (F_w - F_l)$ = **100.0** kN

Equiv leeward net force for bottom section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wb}$ = **-14.5** kN

Net windward force for bottom section; $F_w = F_{w,wb}$ = **3.2** kN

Lack of correlation (cl.7.2.2(3) – Note); f_{corr} = **0.94**; as h/L is 3.447

Overall loading bottom section; $F_{w,b} = f_{corr} \times (F_w - F_l)$ = **16.7** kN

Roof load case 4 - Wind 90, c_{pi} -0.3, $+c_{pe}$

Zone	Ext pressure coefficient c_{pe}	Peak velocity pressure q_p, (kN/m²)	Net pressure p (kN/m²)	Area A_{ref} (m²)	Net force F_w (kN)
F (+ve)	-2.00	0.89	-1.39	1.05	-1.46
G (+ve)	-1.40	0.89	-0.90	1.05	-0.94
H (+ve)	-0.70	0.89	-0.32	8.36	-2.63
I (+ve)	0.20	0.89	0.43	28.41	12.28

Total vertical net force; $F_{w,v}$ = **7.25** kN

Total horizontal net force; $F_{w,h}$ = **0.00** kN

Walls load case 4 - Wind 90, c_{pi} -0.3, $+c_{pe}$

Zone	Ext pressure coefficient c_{pe}	Peak velocity pressure q_p, (kN/m²)	Net pressure p (kN/m²)	Area A_{ref} (m²)	Net force F_w (kN)
A	-1.20	0.89	-0.73	26.79	-19.56
B	-0.80	0.89	-0.40	107.17	-42.66

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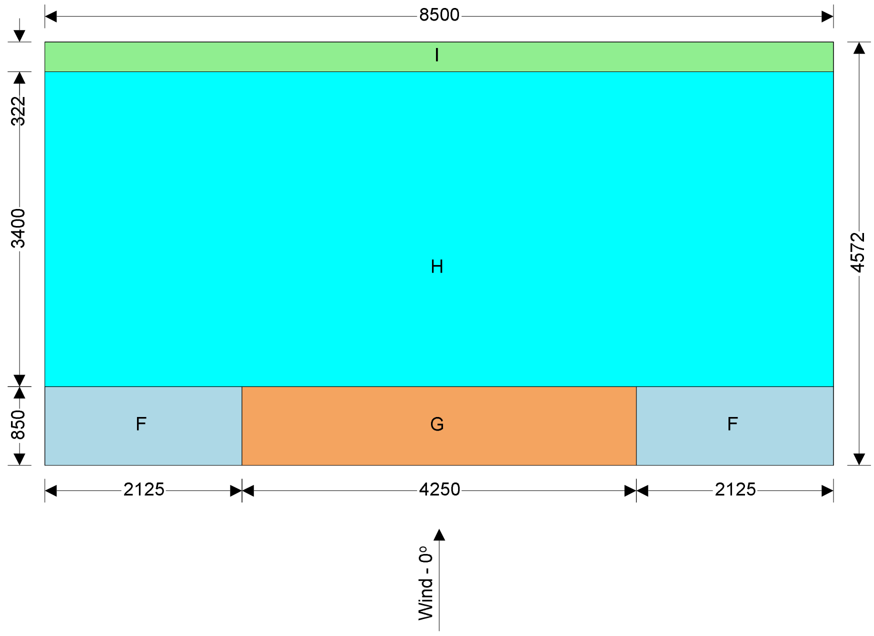
C	-0.50	0.89	-0.15	115.09	-17.15
D_b	0.80	0.43	0.60	20.90	12.49
D_m	0.80	0.84	0.90	92.15	83.10
D_u	0.80	0.89	0.98	20.90	20.57
E	-0.62	0.89	-0.25	133.96	-33.57

Overall loading

Equiv leeward net force for upper section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wu} = \mathbf{-5.2}$ kN
Net windward force for upper section; $F_w = F_{w,wu} = \mathbf{20.6}$ kN
Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} = \mathbf{0.94}$; as h/L is 3.447
Overall loading upper section; $F_{w,u} = f_{corr} \times (F_w - F_l + F_{w,h}) = \mathbf{24.3}$ kN
Equiv leeward net force for middle section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wm} = \mathbf{-23.1}$ kN
Net windward force for middle section; $F_w = F_{w,wm} = \mathbf{83.1}$ kN
Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} = \mathbf{0.94}$; as h/L is 3.447
Overall loading middle section; $F_{w,m} = f_{corr} \times (F_w - F_l) = \mathbf{100.0}$ kN
Equiv leeward net force for bottom section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wb} = \mathbf{-5.2}$ kN
Net windward force for bottom section; $F_w = F_{w,wb} = \mathbf{12.5}$ kN
Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} = \mathbf{0.94}$; as h/L is 3.447
Overall loading bottom section; $F_{w,b} = f_{corr} \times (F_w - F_l) = \mathbf{16.7}$ kN



Plan view - Flat roof

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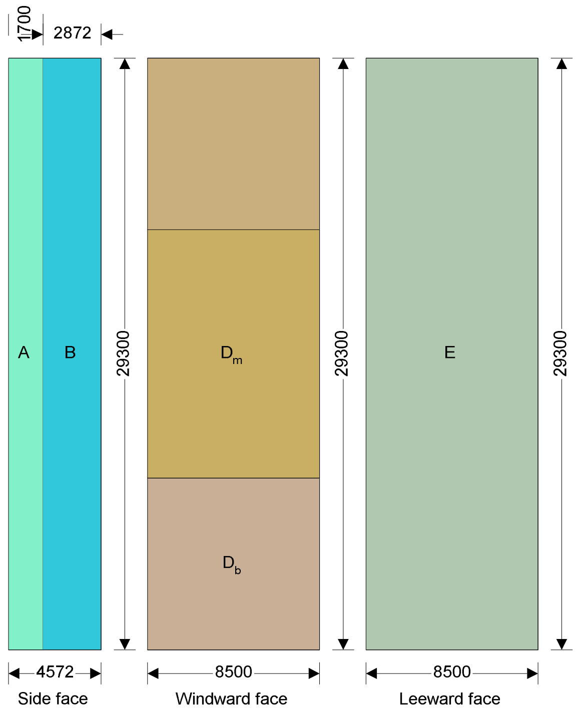

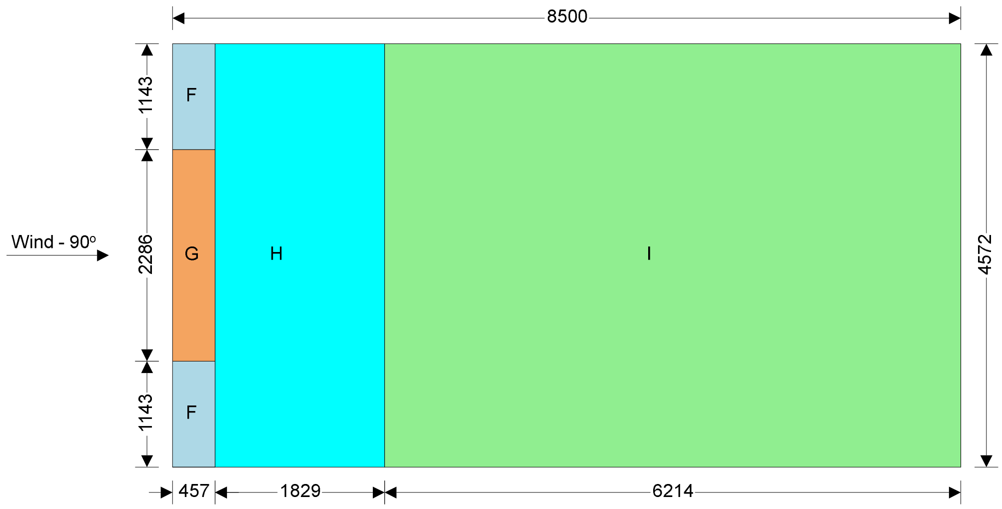

Plan view - Flat roof

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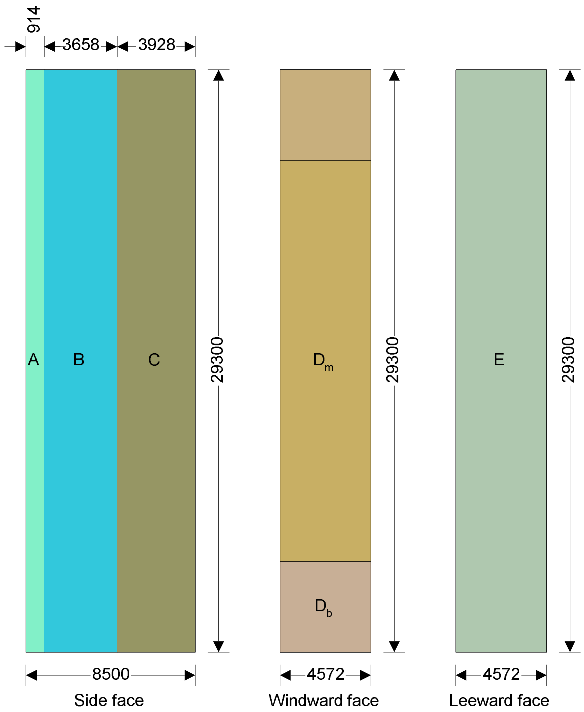

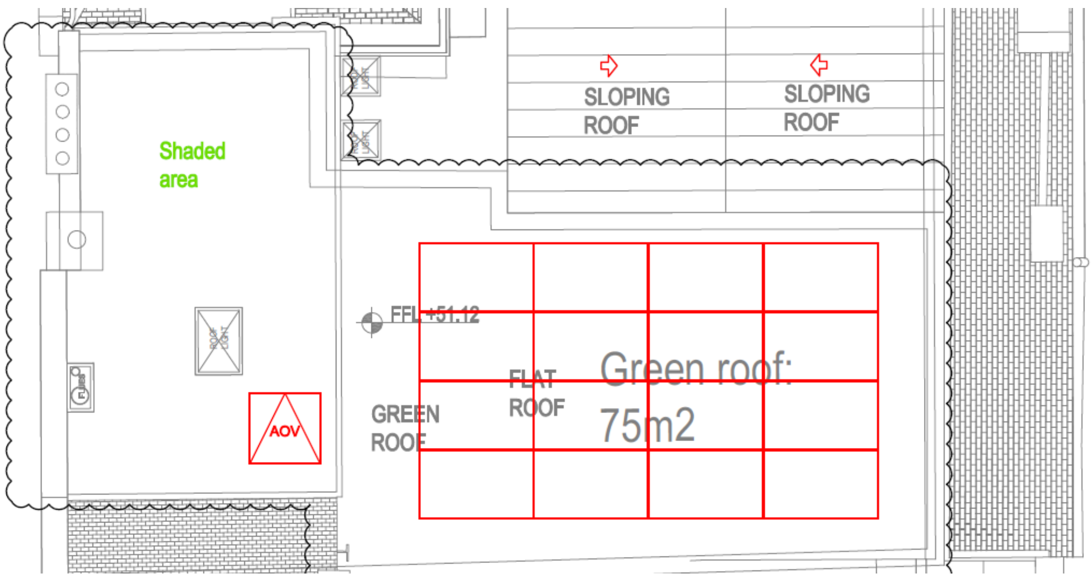

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Conclusion

From the calculated loads we see that each panel weighs 18.5kg and is 1700mm by 1016mm.

Therefore, the weight per m2 = 10.7kg/m2.

The support frame weighs 5kg/m2

To calculate the actual wind uplift on the PV Array we refer to BRE Digest 489.

From our calculations above we know that q = 0.89kN/m2 and that the Net Pressure Coefficients for the Zone where the panels will be placed is -0.7kN/m2.

- ⇨ 0.89 x -0.7 = -0.62kN/m2

To allow for a comfortable factor of safety against uplift we must allow for sufficient ballast for the weight of the panel + the frame and holding down capacity of the ballast to be equal or greater than 1.25 times the uplift load.

The uplift load to be resisted = 0.62 x 1.25 = 0.78kN/m2

The weight of the frame and panels = 16kg or 0.16kN/m2

- ⇨ 0.78kN/m2 – 0.16kN/m2 = **0.62kN/m2 (107kg per panel on the outer panels)**
- ⇨ 0.62kN/m2 – 0.16kN/m2 = **0.46kN/m2 (79kg per panel on the inner panels)**

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Disclaimer:

1. Please note that BMG Surveys have not carried out any checks on the structures ability to accept the above noted loads and therefore cannot be held responsible for any claims should any occur in the future.

2. The Desk Top Appraisal Report has been produced from information supplied by client. BMG Surveys Ltd. cannot be held responsible for any damage caused from the supply of limited information or damage caused due to inaccuracies within the information supplied

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