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STRUCTURAL ROOF LOADING APPRAISAL

GREENIO
RENEWABLE ENERGY EXPERTS

ALL SAINTS CHURCH CV34 5NJ

CALCULATIONS CARRIED OUT IN ACCORDANCE WITH MCS STANDARDS

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NOTE: This report has been carried out in accordance with BS EN 1991-1 BRE, the Digest 489 (2014), MIS 3002 & specifically Sections 4.3.6 to 4.3.8 of the Guide to the Installation of Photovoltaic Systems as required.

1.0 APPLIED LOADING

In considering the applied loading we have designed as noted below:

Dead loads are based on the actual specified make up for the existing roof.

Imposed floor loads are based on the loadings within BS 6399 & Eurocode- 1 (BS EN 1991-1).

Wind loadings are calculated on a site-specific basis.

Applied loads are as follows:

EXISTING ROOF MAKE UP:

DEAD LOADS	Existing Tiles	= 0.55kN/m2
	Existing Felt	= 0.02kN/m2
	Existing Trusses	= 0.15kN/m2
	Total DL	**= 0.72kN/m**
IMPOSED LOADS		
BS 6399:PT3:4.2 & Eurocode- 1 (BS EN 1991-1)	**Roof Load**	**= 0.60kN/m2**

EXISTING ROOF WIND LOADINGS:

Calculated using TEDDS design software for both positive and negative internal pressure and for wind acting both perpendicular and parallel to the front elevation of the building.

EXISTING ROOF SNOW LOADINGS:

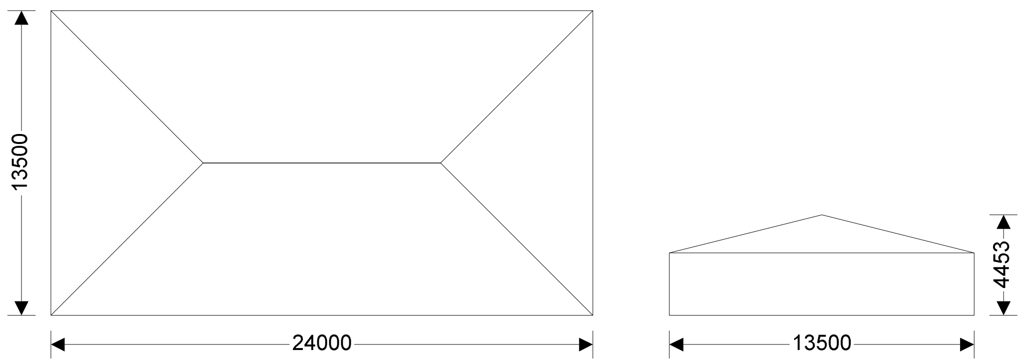
Calculated using TEDDS design software for both basic and where appropriate complex snow loadings.

CALCULATIONS:

WIND LOADING

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

Tedds calculation version 3.0.28



Plan Elevation

Building data

Type of roof;	Hipped
Length of building;	L = **24000** mm
Width of building;	W = **13500** mm
Height to eaves;	H = **2770** mm
Pitch of main slope;	α_0 = **14.0** deg
Pitch of gable slope;	α_{90} = **14.0** deg
Total height;	h = **4453** mm

Basic values

Location;	Birmingham
Wind speed velocity (FigureNA.1);	$v_{b,map}$ = **21.7** m/s
Distance to shore;	L_{shore} = **105.20** km
Altitude above sea level;	A_{alt} = **59.0**m
Altitude factor;	$c_{alt} = A_{alt}/1m \times 0.001 + 1$ = **1.059**
Fundamental basic wind velocity;	$v_{b,0} = v_{b,map} \times c_{alt}$ = **23.0** 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**
Basic wind velocity (Exp. 4.1);	$v_b = c_{dir} \times c_{season} \times v_{b,0} \times c_{prob}$ = **23.0** m/s
Reference mean velocity pressure;	$q_b = 0.5 \times \rho \times v_b^2$ = **0.324** kN/m^2

Orography

Orography factor not significant;	c_o = 1.0
Terrain category;	Country
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 1 part as the height h is less than b (cl.7.2.2)

The velocity pressure for the windward face of the building with a 90 degree wind is to be considered as 1 part as the height h is less than b (cl.7.2.2)

Peak velocity pressure - windward wall - Wind 0 deg

Reference height (at which q is sought);	z = **2770**mm
Displacement height (sheltering effects excluded);	h_{dis} = **0** mm
Exposure factor (Figure NA.7);	c_e = **1.58**
Peak velocity pressure;	$q_p = c_e \times q_b$ = **0.51** kN/m^2

Structural factor

Structural damping;	δ_s = **0.100**
Height of element;	h_{part} = **2770** mm
Size factor (Table NA.3);	c_s = **0.896**
Dynamic factor (Figure NA.9);	c_d = **1.000**
Structural factor;	$c_sc_d = c_s \times c_d$ = **0.896**

Peak velocity pressure - windward wall - Wind 90 deg

Reference height (at which q is sought); z = **2770**mm
Displacement height (sheltering effects excluded); h_{dis} = **0** mm
Exposure factor (Figure NA.7); c_e = **1.58**
Peak velocity pressure; $q_p = c_e \times q_b$ = **0.51** kN/m^2

Structural factor

Structural damping; δ_s = **0.100**
Height of element; h_{part} = **2770** mm
Size factor (Table NA.3); c_s = **0.921**
Dynamic factor (Figure NA.9); c_d = **1.000**
Structural factor; $c_sc_d = c_s \times c_d$ = **0.921**

Peak velocity pressure - roof

Reference height (at which q is sought); z = **4453**mm
Displacement height (sheltering effects excluded); h_{dis} = **0** mm
Exposure factor (Figure NA.7); c_e = **1.84**
Peak velocity pressure; $q_p = c_e \times q_b$ = **0.60** kN/m^2

Structural factor - roof 0 deg

Structural damping; δ_s = **0.100**
Height of element; h_{part} = **4453** mm
Size factor (Table NA.3); c_s = **0.893**
Dynamic factor (Figure NA.9); c_d = **1.000**
Structural factor; $c_sc_d = c_s \times c_d$ = **0.893**

Structural factor - roof 90 deg

Structural damping; δ_s = **0.100**
Height of element; h_{part} = **4453** mm
Size factor (Table NA.3); c_s = **0.916**
Dynamic factor (Figure NA.9); c_d = **1.000**
Structural factor; $c_sc_d = c_s \times c_d$ = **0.916**

Peak velocity pressure for internal pressure

Peak velocity pressure – internal (as roof press.); $q_{p,i}$ = **0.60** 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)	-1.35	0.60	-0.84	3.27	-2.74
G (-ve)	-0.84	0.60	-0.57	17.94	-10.15
H (-ve)	-0.51	0.60	-0.39	98.79	-38.56
I (-ve)	-0.60	0.60	-0.44	103.41	-45.31
J (-ve)	-1.34	0.60	-0.83	11.57	-9.63

K (-ve)	-1.23	0.60	-0.77	5.02	-3.88
L (-ve)	-0.92	0.60	-0.61	11.98	-7.29
M (-ve)	-0.60	0.60	-0.44	81.93	-35.90

Total vertical net force; $F_{w,v}$ = **-148.91** kN

Total horizontal net force; $F_{w,h}$ = **1.78** 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	0.51	-0.67	4.93	-3.30
B	-0.80	0.51	-0.49	19.74	-9.58
C	-0.50	0.51	-0.35	12.73	-4.43
D	0.71	0.51	0.21	66.48	13.70
E	-0.32	0.51	-0.27	66.48	-17.69

Overall loading

Equiv leeward net force for overall section; $F_l = F_{w,wE}$ = **-17.7** kN

Net windward force for overall section; $F_w = F_{w,wD}$ = **13.7** kN

Lack of correlation (cl.7.2.2(3) – Note); f_{corr} = **0.85**; as h/W is 0.330

Overall loading overall section; $F_{w,D} = f_{corr} \times (F_w - F_l + F_{w,h})$ = **28.2** 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)	0.18	0.60	0.27	3.27	0.90
G (+ve)	0.18	0.60	0.27	17.94	4.92
H (+ve)	0.18	0.60	0.27	98.79	27.11
I (+ve)	-0.60	0.60	-0.14	103.41	-14.52
J (+ve)	-1.34	0.60	-0.53	11.57	-6.18
K (+ve)	-1.23	0.60	-0.48	5.02	-2.39
L (+ve)	0.00	0.60	0.18	11.98	2.14
M (+ve)	0.00	0.60	0.18	81.93	14.64

Total vertical net force; $F_{w,v}$ = **25.82** kN

Total horizontal net force; $F_{w,h}$ = **13.55** 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	0.51	-0.37	4.93	-1.83
B	-0.80	0.51	-0.19	19.74	-3.70

C	-0.50	0.51	-0.05	12.73	-0.64
D	0.71	0.51	0.50	66.48	33.50
E	-0.32	0.51	0.03	66.48	2.10

Overall loading

Equiv leeward net force for overall section; $F_l = F_{w,wE} =$ **2.1** kN

Net windward force for overall section; $F_w = F_{w,wD} =$ **33.5** kN

Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} =$ **0.85**; as h/W is 0.330

Overall loading overall section; $F_{w,D} = f_{corr} \times (F_w - F_l + F_{w,h}) =$ **38.2** 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)	-1.35	0.60	-0.86	3.27	-2.80
G (-ve)	-0.84	0.60	-0.58	8.30	-4.79
H (-ve)	-0.51	0.60	-0.40	35.38	-14.06
I (-ve)	-0.60	0.60	-0.45	35.38	-15.80
J (-ve)	-1.34	0.60	-0.85	11.57	-9.84
L (-ve)	-0.92	0.60	-0.62	12.39	-7.70
M (-ve)	-0.60	0.60	-0.45	13.08	-5.84
N (-ve)	-0.42	0.60	-0.35	214.53	-74.71

Total vertical net force; $F_{w,v} =$ **-131.50** kN

Total horizontal net force; $F_{w,h} =$ **0.97** 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/m^2)	Net pressure p (kN/m^2)	Area A_{ref} (m^2)	Net force F_w (kN)
A	-1.20	0.51	-0.68	4.93	-3.37
B	-0.80	0.51	-0.50	19.74	-9.78
C	-0.50	0.51	-0.35	41.81	-14.81
D	0.70	0.51	0.21	37.40	7.86
E	-0.30	0.51	-0.26	37.40	-9.73

Overall loading

Equiv leeward net force for overall section; $F_l = F_{w,wE} =$ **-9.7** kN

Net windward force for overall section; $F_w = F_{w,wD} =$ **7.9** kN

Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} =$ **0.85**; as h/L is 0.186

Overall loading overall section; $F_{w,D} = f_{corr} \times (F_w - F_l + F_{w,h}) =$ **15.8** 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/m^2)	Net pressure p (kN/m^2)	Area A_{ref} (m^2)	Net force F_w (kN)
F (+ve)	0.18	0.60	0.28	3.27	0.91
G (+ve)	0.18	0.60	0.28	8.30	2.30
H (+ve)	0.18	0.60	0.28	35.38	9.80
I (+ve)	-0.60	0.60	-0.15	35.38	-5.26
J (+ve)	-1.34	0.60	-0.55	11.57	-6.39
L (+ve)	0.00	0.60	0.18	12.39	2.21
M (+ve)	0.00	0.60	0.18	13.08	2.34
N (+ve)	0.00	0.60	0.18	214.53	38.33

Total vertical net force; $F_{w,v}$ = **42.91** kN

Total horizontal net force; $F_{w,h}$ = **5.97** 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/m^2)	Net pressure p (kN/m^2)	Area A_{ref} (m^2)	Net force F_w (kN)
A	-1.20	0.51	-0.39	4.93	-1.90
B	-0.80	0.51	-0.20	19.74	-3.90
C	-0.50	0.51	-0.06	41.81	-2.36
D	0.70	0.51	0.51	37.40	18.99
E	-0.30	0.51	0.04	37.40	1.40

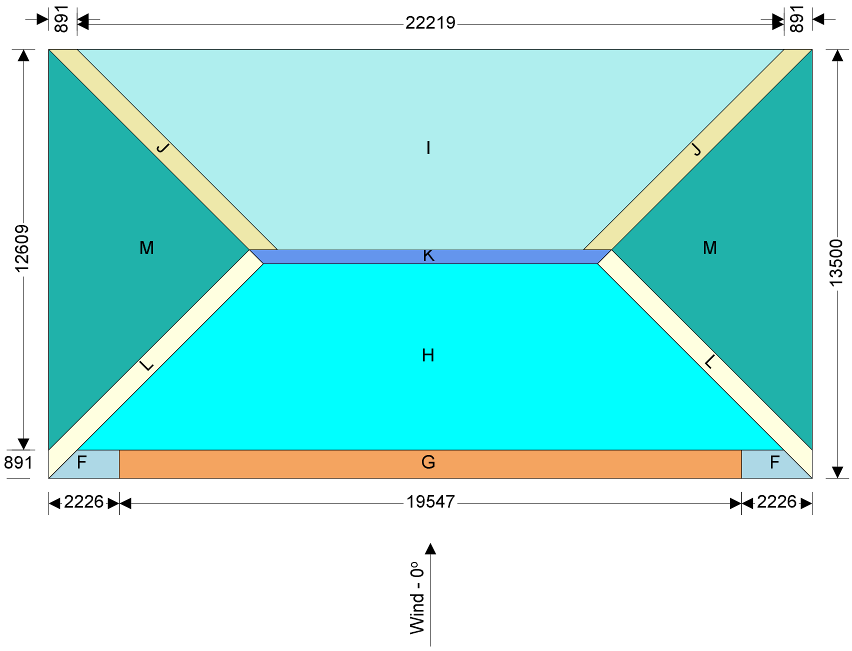
Overall loading

Equiv leeward net force for overall section; $F_l = F_{w,wE}$ = **1.4** kN

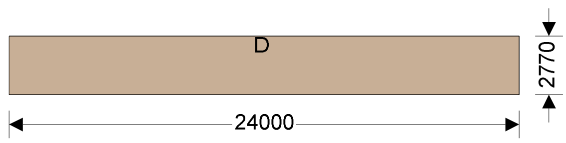
Net windward force for overall section; $F_w = F_{w,wD}$ = **19.0** kN

Lack of correlation (cl.7.2.2(3) – Note); f_{corr} = **0.85**; as h/L is 0.186

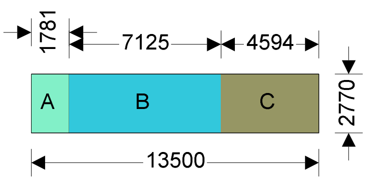
Overall loading overall section; $F_{w,D} = f_{corr} \times (F_w - F_l + F_{w,h})$ = **20.0** kN



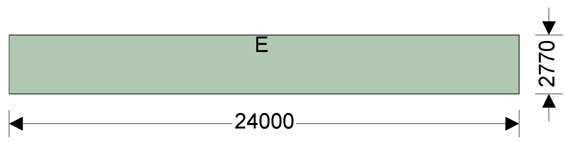
Plan view - Hipped roof



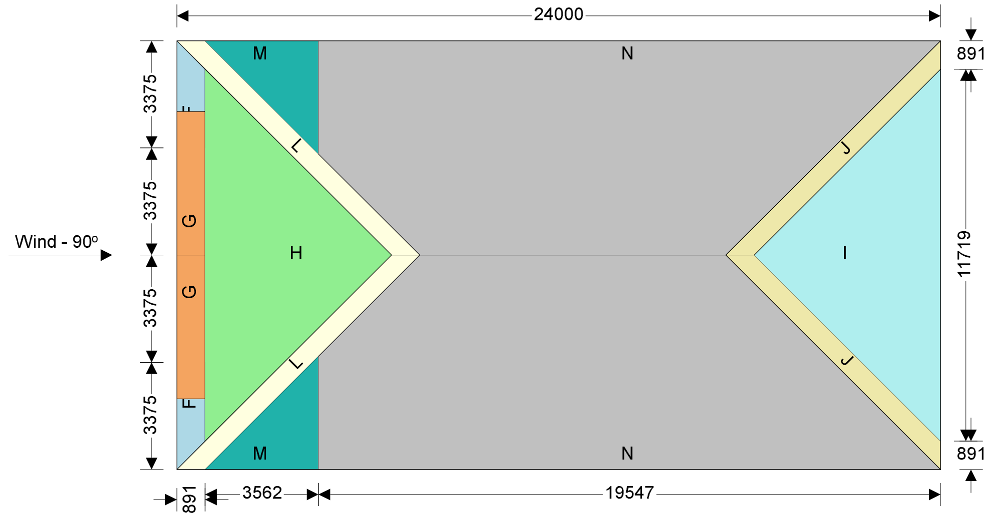
Windward face



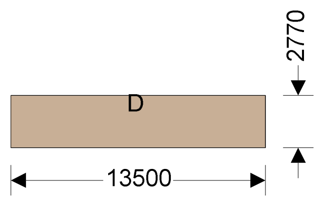
Side face



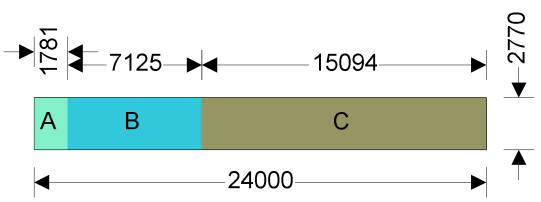
Leeward face



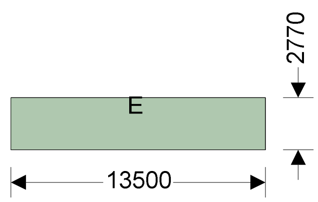
Plan view - Hipped roof



Windward face



Side face



Leeward face

2.0 JUSTIFICATION OF PANELS FOR GRAVITY LOADINGS

From the calculated loads we see that each panel weighs 18.2kg and is 1665mm by 991mm.

Therefore the weight per m2 = 11kg/m2.

The support frame weighs 2kg/m2.

The allowable vertical imposed load is 0.60kN/m2 or 60kg/m2 which is far more than the weight of the panel being placed on the roof.

Once the panel is in situ this area of roof will not be trafficked and so there is no need to consider the actual weight of the panel as being an additional imposed load on the roof. Should anyone stand on the panel it will destroyed, the owner of the property will therefore take strict steps to ensure that no one at any time stands on the panel. Therefore, this area of roof can be considered as carrying less than the design-imposed load indicated in BS EN 1991-1. Therefore, there is no requirement for strengthening as a result of combined imposed load and panel load.

With regards snow loading we see that the snow load is 0.34kN/m2. This load will be cumulative to the weight of the panel. However, with the panel and frame weighing 13kg/m2 this combined loading is equal to or less than the design-imposed load of 0.60kN/m2.

The combined snow and panel load would therefore require no additional strengthening works in order to carry this increase in load. The existing roof structure is therefore adequate as it stands at present.

SNOW LOADING

In accordance with EN1991-1-3:2003+A1:2015 incorporating corrigenda dated December 2004 and March 2009 and the UK national annex NA+A1:2015 to BS EN 1991-1-3:2003+A1:2015 incorporating Corrigendum No.1

Tedds calculation version 1.0.14

Characteristic ground snow load

Location;	Birmingham
Site altitude above sea level (user modified value);	A = **59** m
Zone number;	Z = **3.0**
Density of snow;	γ = **2.00** kN/m^3
Characteristic ground snow load;	s_k = ((0.15 + (0.1 × Z + 0.05)) + ((A - 100m) / 525m)) × 1kN/m^2 = **0.42** kN/m^2
Exposure coefficient (Normal);	C_e = **1.0**
Thermal coefficient;	C_t = **1.0**
Snow fence;	Not present

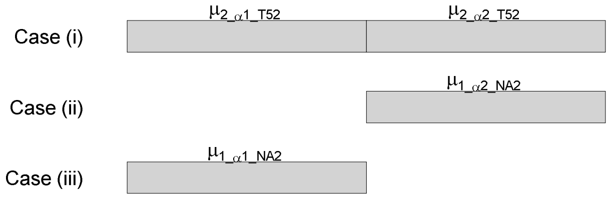
Building details

Roof type;	Duopitch
Width of roof (left on elevation);	b_1 = **6.75** m
Width of roof (right on elevation);	b_2 = **6.75** m
Slope of roof (left on elevation);	α_1 = **14.00** deg
Slope of roof (right on elevation);	α_2 = **14.00** deg

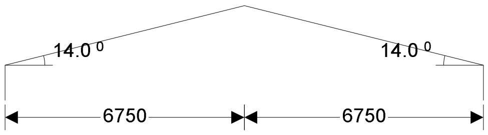
Shape coefficients

Shape coefficient roof (Table 5.2);	$\mu_{2\_\alpha1\_T52}$ = **0.80**
Shape coefficient roof (Table 5.2);	$\mu_{2\_\alpha2\_T52}$ = **0.80**
Shape coefficient roof (Table UK NA.2);	$\mu_{1\_\alpha1\_NA2}$ = **0.80**

Shape coefficient roof (Table UK NA.2); $\mu_{1\_\alpha2\_NA2}$ = **0.80**



Shape coef	Coef	Loading (kN/m²)
$\mu_{2\_\alpha1\_T52}$	0.800	0.34
$\mu_{2\_\alpha2\_T52}$	0.800	0.34
$\mu_{1\_\alpha1\_NA2}$	0.800	0.34
$\mu_{1\_\alpha2\_NA2}$	0.800	0.34



Elevation on gable roof

Loadcase 1 Table 5.2

Loading to roof 1 (LHS); $s_{1\_1} = \mu_{2\_\alpha1\_T52} \times C_e \times C_t \times s_k$ = **0.34** kN/m²

Loading to roof 2 (RHS); $s_{2\_1} = \mu_{2\_\alpha2\_T52} \times C_e \times C_t \times s_k$ = **0.34** kN/m²

Loadcase 2 UK NA.2

Loading to roof 1 (LHS); $s_{1\_2} = 0 \times C_e \times C_t \times s_k$ = **0.00** kN/m²

Loading to roof 2 (RHS); $s_{2\_2} = \mu_{1\_\alpha2\_NA2} \times C_e \times C_t \times s_k$ = **0.34** kN/m²

Loadcase 3 UK NA.2

Loading to roof 1 (LHS); $s_{1\_3} = \mu_{1\_\alpha1\_NA2} \times C_e \times C_t \times s_k$ = **0.34** kN/m²

Loading to roof 2 (RHS); $s_{2\_3} = 0 \times C_e \times C_t \times s_k$ = **0.00** kN/m²

Gravity Loadings During Installation

The total additional load permitted on the roof structure for the installation of the PV panels is 0.60kN/m2 or 60kg/m2. The maximum permitted point loading during construction is 0.9kN or 90kg,

In accordance with BS EN 1991-1, 0.60kN/m2 or 0.9kN point loads are permitted for non-accessble roofs except for normal maintenance and repairs. Therefore the existing roof has been desgined for these allowable loads.

During solar panel installation we recommend plywood sheets or other appropriate load spreaders are used to adequately distrubute the load to avoid comprimising the 0.60kN/m2 or 0.9kN values. If the PV panels and associated equipment are to be stored on the roof during installation these should be dispersed in a manner that the weight does not exceed 0.60kN/m2. Access to the roof is not permitted during periods of snow.

The roof structure is uniform across its entire area and does not appear to be any strong points or weakend areas, so the points listed are considered to applicable for the whole structure.

3.0 JUSTIFICATION OF PANELS FOR UPLIFT LOADINGS

From the calculations we see that the panels should ideally be placed within the central zones of the roof where there is little or no wind uplift.

Given that the panel fixings will transfer the load into the existing roof and the roof was originally designed for this wind load, no strengthening works will be required to the roof structure.

The applied wind load where the panels are to be placed is 0.27kN/m2.
(Should the panels encroach on other Zones the applied loadings will vary. Please see Load Case 2 table and Plan View 0 Degrees above for Zone Areas and Dimensions.)

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

From our calculations above we know that q = 0.60kN/m2 and where a module is less than 0.3m from the roof surface the Wind Uplift Net Pressure Coefficients for the panels in the centre of the roof is -1.50

- ⇨ -0.60 x -1.50 = -0.90kN/m2 (All roof fixings have to be able to withstand this wind uplift load.)

4.0 CONCLUSIONS

From the calculations, we see that the combined system (0.13kN/m2) + snow load (0.34kN/m2) = (0.47kN/m2) is less than or equal to the design-imposed load of 0.60kN/m2 therefore the proposed solar panels can safely be fixed to the existing roof structure with no strengthening works being required.