ROOF LOADING APPRAISAL

ACT
Associated Clean Technologies

TITANIC MILLS,
LOW WESTWOOD LN, LINTHWAITE, HUDDERSFIELD HD7 5UN

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CALCULATIONS CARRIED OUT IN ACCORDANCE WITH MCS SOLAR PV STANDARDS

TABLE OF CONTENTS

NOTE: This report has been carried out in accordance with BS EN 1991-1, BRE Digest 489 (2015) and (Where required) Section 5.9 of MIS 3002 The Solar PV Standard.

1.0 SITE SURVEY INFORMATION

BMG Surveys Ltd have been commissioned to carry out a structural roof loading appraisal of the afore mentioned commercial property for its suitability for a Solar PV Installation. Our checks included an onsite inspection and following the collation of the required information a set of calculations have been carried out in respect of the existing roof loadings and the proposed loadings for a Solar PV installation.

Our on-site inspection was carried out on a sunny day. Our inspections cover all areas of the property and particular attention was paid to the roof and its structure.

Our visual inspection was carried out of all visible aspects of the properties structure including walls & roof both externally and internally. It was found that the properties primary structure and roof structure look to be in fair condition with no signs of failure or deflection.

We conclude that the onsite inspection of the property and our subsequent design checks within sections 2.0, 3.0 & 4.0 of this report confirm that the roof and supporting structure can safely accept the loadings from the proposed Solar PV installation and we have no concerns over the structures ability to accept the loadings.

2.0 APPLIED LOADINGS

In considering the applied loading, we have assessed 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) in line with the date of design/construction.
- Wind & Snow loadings are calculated on a site-specific basis in line with European Codes of Practice.
- The property has been built in accordance with relevant building codes.

Applied loads are as follows:

EXISTING ROOF MAKE UP:

DEAD LOAD

Trapezoidal Roof Sheet	Standing Seam Roof System	0.15
	Sarking Boards	0.10
	Timber Purlins	0.10
	Total	0.35

IMPOSED LOADS

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.

The positive pressures on the building have already been considered at design stage and installing Solar PV does not increase or reduce these loadings, therefore positive wind pressures do not need to be considered in this loading assessment.

Negative wind pressures are used to calculate the wind uploads and determine the fixing resistance for any mounting frame designs.

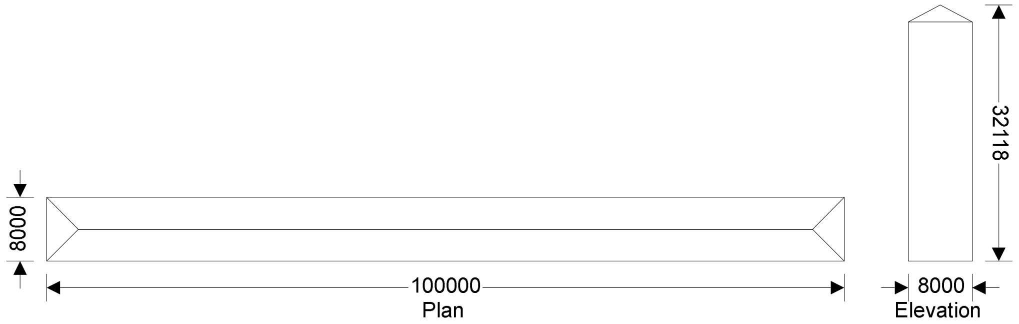
EXISTING ROOF SNOW LOADINGS:

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

WIND LOADING

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

Tedds calculation version 3.0.29



Building data

Type of roof;	Hipped
Length of building;	L = **100000** mm
Width of building;	W = **8000** mm
Height to eaves;	H = **30000** mm
Pitch of main slope;	α_0 = **27.9** deg
Pitch of gable slope;	α_{90} = **27.9** deg
Total height;	h = **32118** mm

Basic values

Location;	Huddersfield
Wind speed velocity (FigureNA.1);	$v_{b,map}$ = **22.5** m/s
Distance to shore;	L_{shore} = **68.30** km
Altitude above sea level;	A_{alt} = **130.0**m
Altitude factor;	$c_{alt} = A_{alt}/1m \times 0.001 + 1$ = **1.130**
Fundamental basic wind velocity;	$v_{b,0} = v_{b,map} \times c_{alt}$ = **25.4** 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);	$v_b = c_{dir} \times c_{season} \times v_{b,0} \times c_{prob}$ = **25.4** m/s
Reference mean velocity pressure;	$q_b = 0.5 \times \rho \times v_b^2$ = **0.396** 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 3 parts as the height h is greater than 2b (cl.7.2.2)

Peak velocity pressure - windward wall - Wind 0 deg

Reference height (at which q is sought);	z = **30000**mm
Displacement height (sheltering effects excluded);	h_{dis} = **0** mm
Exposure factor (Figure NA.7);	c_e = **3.08**
Peak velocity pressure;	$q_p = c_e \times q_b$ = **1.22** kN/m^2

Structural factor

Structural damping;	δ_s = **0.100**
Height of element;	h_{part} = **30000** mm
Size factor (Table NA.3);	c_s = **0.858**
Dynamic factor (Figure NA.9);	c_d = **1.000**
Structural factor;	$c_sc_d = c_s \times c_d$ = **0.858**

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

Reference height (at which q is sought);	z = **8000**mm

Displacement height (sheltering effects excluded);	h_{dis} = **0** mm
Exposure factor (Figure NA.7);	c_e = **2.21**
Peak velocity pressure;	$q_p = c_e \times q_b$ = **0.88** kN/m^2

Structural factor

Structural damping;	δ_s = **0.100**
Height of element;	h_{part} = **8000** mm
Size factor (Table NA.3);	c_s = **0.927**
Dynamic factor (Figure NA.9);	c_d = **1.062**
Structural factor;	$c_sc_d = c_s \times c_d$ = **0.985**

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

Reference height (at which q is sought);	z = **22000**mm
Displacement height (sheltering effects excluded);	h_{dis} = **0** mm
Exposure factor (Figure NA.7);	c_e = **2.87**
Peak velocity pressure;	$q_p = c_e \times q_b$ = **1.14** kN/m^2

Structural factor

Structural damping;	δ_s = **0.100**
Height of element;	h_{part} = **14000** mm
Size factor (Table NA.3);	c_s = **0.930**
Dynamic factor (Figure NA.9);	c_d = **1.062**
Structural factor;	$c_sc_d = c_s \times c_d$ = **0.988**

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

Reference height (at which q is sought);	z = **30000**mm
Displacement height (sheltering effects excluded);	h_{dis} = **0** mm
Exposure factor (Figure NA.7);	c_e = **3.08**
Peak velocity pressure;	$q_p = c_e \times q_b$ = **1.22** kN/m^2

Structural factor

Structural damping;	δ_s = **0.100**
Height of element;	h_{part} = **8000** mm
Size factor (Table NA.3);	c_s = **0.948**
Dynamic factor (Figure NA.9);	c_d = **1.062**
Structural factor;	$c_sc_d = c_s \times c_d$ = **1.007**

Structural factor

Structural damping;	δ_s = **0.100**
Height of element;	h_{part} = **30000** mm
Size factor (Table NA.3);	c_s = **0.914**
Dynamic factor (Figure NA.9);	c_d = **1.062**
Structural factor;	$c_sc_d = c_s \times c_d$ = **0.971**

Peak velocity pressure - roof

Reference height (at which q is sought);	z = **32118**mm
Displacement height (sheltering effects excluded);	h_{dis} = **0** mm
Exposure factor (Figure NA.7);	c_e = **3.13**
Peak velocity pressure;	$q_p = c_e \times q_b$ = **1.24** kN/m^2

Structural factor - roof 0 deg

Structural damping; δ_s = **0.100**

Height of element; h_{part} = **32118** mm

Size factor (Table NA.3); c_s = **0.858**

Dynamic factor (Figure NA.9); c_d = **1.000**

Structural factor; $c_sc_d = c_s \times c_d$ = **0.859**

Structural factor - roof 90 deg

Structural damping; δ_s = **0.100**

Height of element; h_{part} = **32118** mm

Size factor (Table NA.3); c_s = **0.911**

Dynamic factor (Figure NA.9); c_d = **1.062**

Structural factor; $c_sc_d = c_s \times c_d$ = **0.968**

Peak velocity pressure for internal pressure

Peak velocity pressure – internal (as roof press.); $q_{p,i}$ = **1.24** 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)	-0.61	1.24	-0.90	186.76	-167.87
I (-ve)	-0.60	1.24	-0.89	77.03	-68.25
L (-ve)	-0.99	1.24	-1.30	34.80	-45.13

Total vertical net force; $F_{w,v}$ = **-248.56** kN

Total horizontal net force; $F_{w,h}$ = **-46.62** 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	1.22	-1.51	240.00	-361.30
D	0.80	1.22	0.59	3000.00	1771.75
E	-0.65	1.22	-0.93	3000.00	-2789.33

Overall loading

Equiv leeward net force for overall section; $F_l = F_{w,wE}$ = **-2789.3** kN

Net windward force for overall section; $F_w = F_{w,wD}$ = **1771.7** kN

Lack of correlation (cl.7.2.2(3) – Note); f_{corr} = **0.96**; as h/W is 4.015

Overall loading overall section; $F_{w,D} = f_{corr} \times (F_w - F_l + F_{w,h})$ = **4347.7** 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/m²)	Net pressure p (kN/m²)	Area A_{ref} (m²)	Net force F_w (kN)
F (+ve)	0.72	1.24	1.13	186.76	211.67
I (+ve)	-0.60	1.24	-0.27	77.03	-20.53
L (+ve)	0.00	1.24	0.37	34.80	12.94

Total vertical net force; $F_{w,v}$ = **180.35** kN

Total horizontal net force; $F_{w,h}$ = **108.65** 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/m²)	Net pressure p (kN/m²)	Area A_{ref} (m²)	Net force F_w (kN)
A	-1.20	1.22	-0.89	240.00	-212.61
D	0.80	1.22	1.21	3000.00	3630.32
E	-0.65	1.22	-0.31	3000.00	-930.76

Overall loading

Equiv leeward net force for overall section; $F_l = F_{w,wE}$ = **-930.8** kN

Net windward force for overall section; $F_w = F_{w,wD}$ = **3630.3** kN

Lack of correlation (cl.7.2.2(3) – Note); f_{corr} = **0.96**; as h/W is 4.015

Overall loading overall section; $F_{w,D} = f_{corr} \times (F_w - F_l + F_{w,h})$ = **4497.2** 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/m²)	Net pressure p (kN/m²)	Area A_{ref} (m²)	Net force F_w (kN)
F (-ve)	-0.61	1.24	-0.98	2.90	-2.84
G (-ve)	-0.54	1.24	-0.90	3.62	-3.25
H (-ve)	-0.24	1.24	-0.54	11.59	-6.23
I (-ve)	-0.60	1.24	-0.97	11.59	-11.21
J (-ve)	-1.31	1.24	-1.82	6.52	-11.88
L (-ve)	-0.99	1.24	-1.43	7.24	-10.36
M (-ve)	-0.60	1.24	-0.97	11.59	-11.21
N (-ve)	-0.49	1.24	-0.83	850.18	-706.06

Total vertical net force; $F_{w,v}$ = **-674.35** kN

Total horizontal net force; $F_{w,h}$ = **5.04** 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	1.22	-1.67	48.00	-80.17
B	-0.80	1.22	-1.20	192.00	-229.65
C	-0.50	1.22	-0.84	2760.00	-2319.72

D_b	0.71	0.88	0.36	64.00	23.29
D_m	0.71	1.14	0.55	112.00	61.58
D_u	0.71	1.22	0.62	64.00	39.97
E	-0.32	1.22	-0.63	240.00	-150.22

Overall loading

Equiv leeward net force for upper section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wu} =$ **-40.1** kN
Net windward force for upper section; $F_w = F_{w,wu} =$ **40.0** kN
Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} =$ **0.85**; as h/L is 0.321
Overall loading upper section; $F_{w,u} = f_{corr} \times (F_w - F_l + F_{w,h}) =$ **72.3** kN
Equiv leeward net force for middle section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wm} =$ **-70.1** kN
Net windward force for middle section; $F_w = F_{w,wm} =$ **61.6** kN
Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} =$ **0.85**; as h/L is 0.321
Overall loading middle section; $F_{w,m} = f_{corr} \times (F_w - F_l) =$ **111.9** kN
Equiv leeward net force for bottom section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wb} =$ **-40.1** kN
Net windward force for bottom section; $F_w = F_{w,wb} =$ **23.3** kN
Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} =$ **0.85**; as h/L is 0.321
Overall loading bottom section; $F_{w,b} = f_{corr} \times (F_w - F_l) =$ **53.8** 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/m²)	Net pressure p (kN/m²)	Area A_{ref} (m²)	Net force F_w (kN)
F (+ve)	0.72	1.24	1.23	2.90	3.56
G (+ve)	0.46	1.24	0.92	3.62	3.33
H (+ve)	0.37	1.24	0.82	11.59	9.47
I (+ve)	-0.60	1.24	-0.35	11.59	-4.03
J (+ve)	-1.31	1.24	-1.20	6.52	-7.84
L (+ve)	0.00	1.24	0.37	7.24	2.69
M (+ve)	0.00	1.24	0.37	11.59	4.31
N (+ve)	0.00	1.24	0.37	850.18	316.02

Total vertical net force; $F_{w,v} =$ **289.45** kN
Total horizontal net force; $F_{w,h} =$ **13.21** 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	1.22	-1.05	48.00	-50.43
B	-0.80	1.22	-0.58	192.00	-110.70
C	-0.50	1.22	-0.22	2760.00	-609.83
D_b	0.71	0.88	0.98	64.00	62.94
D_m	0.71	1.14	1.17	112.00	130.97

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D_u	0.71	1.22	1.24	64.00	79.61
E	-0.32	1.22	-0.01	240.00	-1.53

Overall loading

Equiv leeward net force for upper section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wu} =$ **-0.4** kN

Net windward force for upper section; $F_w = F_{w,wu} =$ **79.6** kN

Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} =$ **0.85**; as h/L is 0.321

Overall loading upper section; $F_{w,u} = f_{corr} \times (F_w - F_l + F_{w,h}) =$ **79.2** kN

Equiv leeward net force for middle section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wm} =$ **-0.7** kN

Net windward force for middle section; $F_w = F_{w,wm} =$ **131.0** kN

Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} =$ **0.85**; as h/L is 0.321

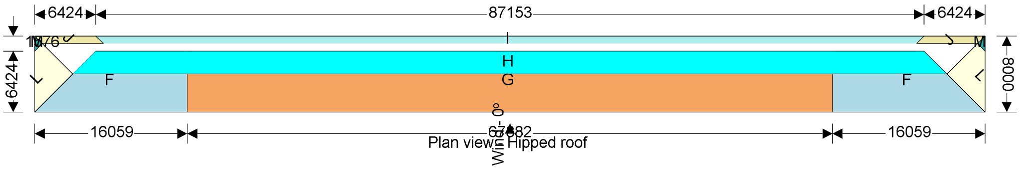
Overall loading middle section; $F_{w,m} = f_{corr} \times (F_w - F_l) =$ **111.9** kN

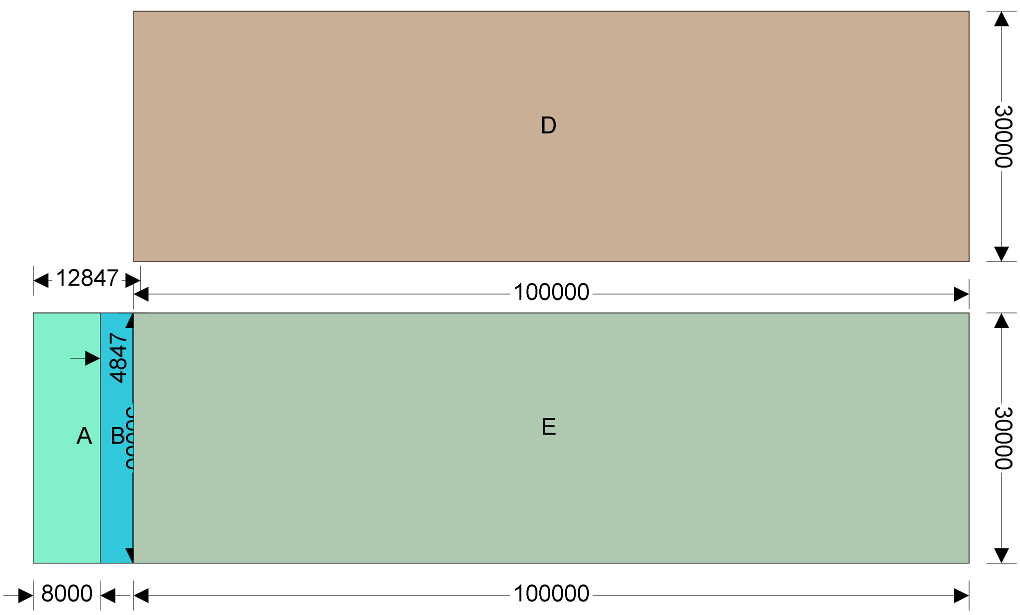
Equiv leeward net force for bottom section; $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wb} =$ **-0.4** kN

Net windward force for bottom section; $F_w = F_{w,wb} =$ **62.9** kN

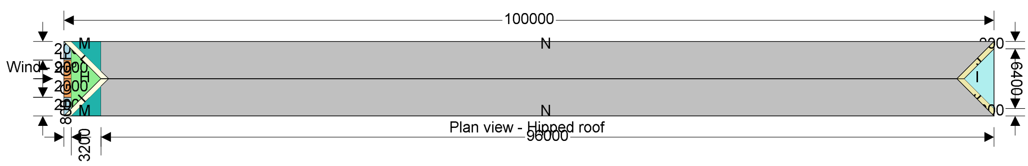
Lack of correlation (cl.7.2.2(3) – Note); $f_{corr} =$ **0.85**; as h/L is 0.321

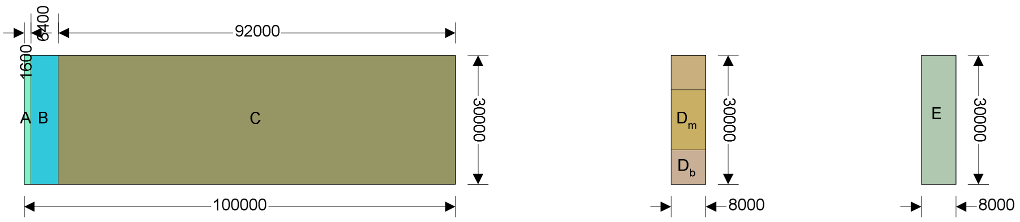
Overall loading bottom section; $F_{w,b} = f_{corr} \times (F_w - F_l) =$ **53.8** kN





Side face Leeward face





Side face Windward face Leeward face

3.0 JUSTIFICATION OF PANELS FOR GRAVITY LOADINGS

3.1 Proposed PV Loadings

The main gravity loading within this assessment is the PV panel and frame loading which is details below:

Panel Size: 1762mm x 1134mm.
Panel Weight: 21.8kg
Support Frame: 2kg/m2

⇨ 21.8kg / (1.762m x 1.134m) + 2kg/m2 = 12.9kg/m2 or **0.13kN/m2.**

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 be 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.

3.2 Snow Load Assessment

When carrying out a roof loading assessment for an installation of PV Panels we need to consider the combined loadings from both the PV Panels and the loadings from snow & snow drift.

With regards snow loading we see that the snow load is 0.53kN/m2. This load will be cumulative to the weight of the panel and frame loadings which are noted within Section 2.1 of this report.

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;	Huddersfield
Site altitude above sea level (user modified value);	A = **130** m
Zone number (user modified value);	Z = **4.0**
Density of snow;	γ = **2.00** kN/m^3
Characteristic ground snow load;	$s_k = ((0.15 + (0.1 \times Z + 0.05)) + ((A - 100m) / 525m)) \times 1kN/m^2 =$ **0.66** kN/m^2
Exposure coefficient (Normal);	C_e = **1.0**
Thermal coefficient;	C_t = **1.0**
Snow fence;	Not present

Building details

Roof type;	Multispan
Width of roof 1 (LHS on left building);	b_1 = **4.00** m
Width of roof 2 (RHS on left building);	b_2 = **4.00** m
Width of roof 3 (LHS on right building);	b_3 = **4.00** m
Width of roof 4 (RHS on right building);	b_4 = **4.00** m
Average roof height at valley;	h_{avg} = **2.12** m
Slope of roof 1 (LHS of left building);	α_1 = **27.90** deg
Slope of roof (RHS of left building);	α_2 = **27.90** deg

Slope of roof 3 (LHS of right building); α_3 = **27.90** deg

Slope of roof 4 (RHS of right building); α_4 = **27.90** deg

Shape coefficients

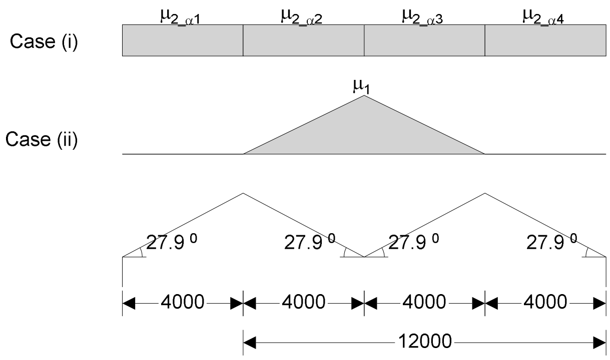
Shape coefficient roof(Table 5.2); $\mu_{2\_\alpha 1}$ = **0.80**

Shape coefficient roof(Table 5.2); $\mu_{2\_\alpha 2}$ = **0.80**

Shape coefficient roof(Table 5.2); $\mu_{2\_\alpha 3}$ = **0.80**

Shape coefficient roof(Table 5.2); $\mu_{2\_\alpha 4}$ = **0.80**

Shape coefficient roof (Annex B2); $\mu_1 = \min(2\text{kN/m}^3 \times h_{avg} / s_k, 2 \times (b_2 + b_3 + \max(b_1, b_4)) / (b_2 + b_3), 5)$ = **3.00**



Elevation on gable roof

Shape coef	Coef	Loading (kN/m²)
$\mu_{2\_\alpha 1}$	0.800	0.53
$\mu_{2\_\alpha 2}$	0.800	0.53
$\mu_{2\_\alpha 3}$	0.800	0.53
$\mu_{2\_\alpha 4}$	0.800	0.53
μ_1	3.000	1.97

Loadcase1 Table 5.2

Loading to roof 1; $s_{1\_1} = \mu_{2\_\alpha 1} \times C_e \times C_t \times s_k$ = **0.53** kN/m²

Loading to roof 2; $s_{2\_1} = \mu_{2\_\alpha 2} \times C_e \times C_t \times s_k$ = **0.53** kN/m²

Loading to roof 3; $s_{3\_1} = \mu_{2\_\alpha 3} \times C_e \times C_t \times s_k$ = **0.53** kN/m²

Loading to roof 4; $s_{4\_1} = \mu_{2\_\alpha 4} \times C_e \times C_t \times s_k$ = **0.53** kN/m²

Loadcase 2 Annex B2

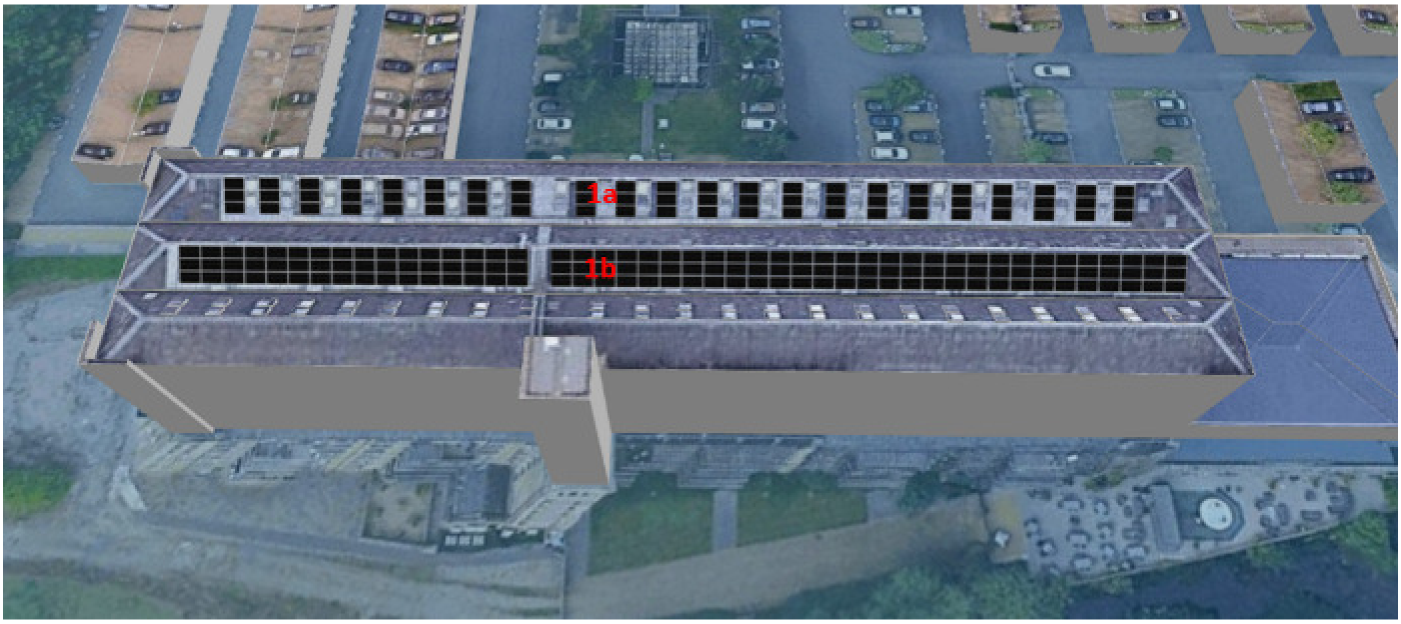
Loading to roof 1; $s_{1\_2} = 0 \times s_k$ = **0.00** kN/m²

Loading to avg roof 2 & 3; $s_{2\_2} = \mu_1 \times s_k$ = **1.97** kN/m²

Loading to roof 4; $s_{3\_2} = 0 \times s_k$ = **0.00** kN/m²

3.3 Snow Drift

The proposed Solar PV panels should be situated a minimum of 1.5 meters away from the valley.



3.4 Solar PV System Loadings to Resist Wind Uplift

From the calculations we see that the positive wind load is 1.13kN/m2.
(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 (2015).

From our calculations above we know that the negative wind loading, q = 1.24kN/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

⇨ -1.24 x -1.50 = -1.86kN/m2 (All roof fixings have to be able to withstand this wind uplift load.)

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

3.5 Advanced Structure Check

TIMBER BEAM ANALYSIS & DESIGN TO EN1995-1-1:2004

In accordance with EN1995-1-1:2004 + A2:2014 and Corrigendum No.1 and the UK National Annex incorporating National Amendment No.1

Tedds calculation version 1.7.05

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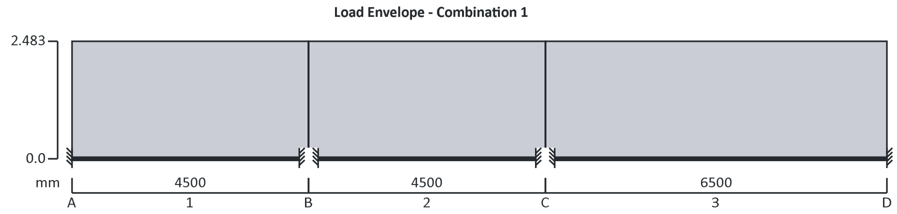
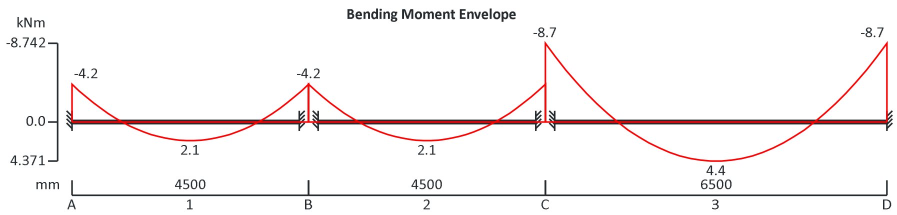
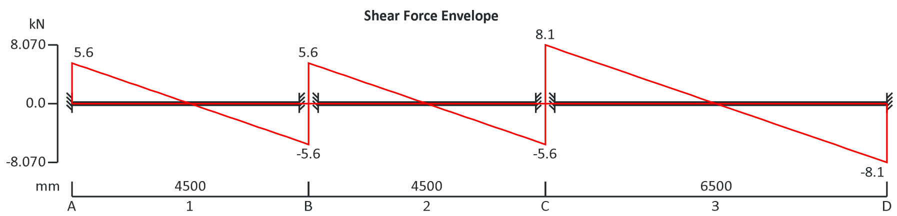






Applied loading

Beam loads

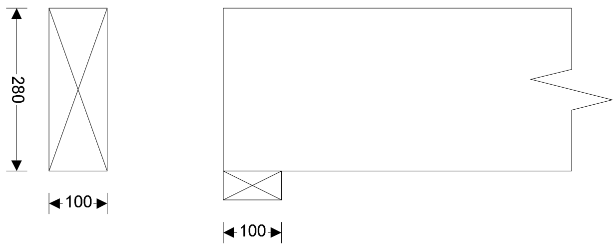
Dead	Dead full UDL 0.380 kN/m
Snow	Snow full UDL 1.970 kN/m

Load combinations

Load combination 1	Support A	Dead × 1.35
		Snow × 1.00
	Span 1	Dead × 1.35
		Snow × 1.00
	Support B	Dead × 1.35
		Snow × 1.00
	Span 2	Dead × 1.35
		Snow × 1.00
	Support C	Dead × 1.35
		Snow × 1.00
	Span 3	Dead × 1.35
		Snow × 1.00
	Support D	Dead × 1.35
		Snow × 1.00

Analysis results

Maximum moment;	M_{max} = **4.371** kNm;	M_{min} = **-8.742** kNm
Design moment;	M = max(abs(M_{max}),abs(M_{min})) = **8.742** kNm	
Maximum shear;	F_{max} = **8.070** kN;	F_{min} = **-8.070** kN
Design shear;	F = max(abs(F_{max}),abs(F_{min})) = **8.070** kN	
Total load on beam;	W_{tot} = **38.487** kN	
Reactions at support A;	R_{A_max} = **5.587** kN;	R_{A_min} = **5.587** kN
Unfactored dead load reaction at support A;	R_{A_Dead} = **0.855** kN	
Unfactored snow load reaction at support A;	R_{A_Snow} = **4.433** kN	
Reactions at support B;	R_{B_max} = **11.174** kN;	R_{B_min} = **11.174** kN
Unfactored dead load reaction at support B;	R_{B_Dead} = **1.710** kN	
Unfactored snow load reaction at support B;	R_{B_Snow} = **8.865** kN	
Reactions at support C;	R_{C_max} = **13.657** kN;	R_{C_min} = **13.657** kN
Unfactored dead load reaction at support C;	R_{C_Dead} = **2.090** kN	
Unfactored snow load reaction at support C;	R_{C_Snow} = **10.835** kN	
Reactions at support D;	R_{D_max} = **8.070** kN;	R_{D_min} = **8.070** kN
Unfactored dead load reaction at support D;	R_{D_Dead} = **1.235** kN	
Unfactored snow load reaction at support D;	R_{D_Snow} = **6.403** kN	



Timber section details

Breadth of timber sections;	b = **100** mm
Depth of timber sections;	h = **280** mm
Number of timber sections in member;	N = **1**
Overall breadth of timber member;	b_b = N × b = **100** mm
Inclination of section;	θ = **27.9** deg
Timber strength class - EN 338:2016 Table 1;	**C24**

Member details

Load duration - cl.2.3.1.2;	**Medium-term**
Service class of timber - cl.2.3.1.3;	**1**
Length of span 1;	L_{s1} = **4500** mm
Length of span 2;	L_{s2} = **4500** mm
Length of span 3;	L_{s3} = **6500** mm
Length of bearing;	L_b = **100** mm

Section properties

Cross sectional area of member;	A = N × b × h = **28000** mm^2
Section modulus;	W_y = N × b × h^2 / 6 = **1306667** mm^3
	W_z = h × (N × b)^2 / 6 = **466667** mm^3

Second moment of area;	$I_y = N \times b \times h^3 / 12 =$ **182933333** mm^4
	$I_z = h \times (N \times b)^3 / 12 =$ **23333333** mm^4
Radius of gyration;	$r_y = \sqrt{(I_y / A)} =$ **80.8** mm
	$r_z = \sqrt{(I_z / A)} =$ **28.9** mm
Second moment of area of rotated section;	$I_\theta = (I_y + I_z) / 2 + (I_y - I_z) \times \cos(2 \times \theta) / 2 =$ **147987587** mm^4

Partial factor for material properties and resistances

Partial factor for material properties - Table 2.3;	$\gamma_M =$ **1.300**

Modification factors

Modification factor for load duration and moisture content - Table 3.1

	$k_{mod} =$ **0.800**
Deformation factor for service classes - Table 3.2;	$k_{def} =$ **0.600**
Depth factor for bending - exp.3.1;	$k_{h.m} =$ **1.000**
Depth factor for tension - exp.3.1;	$k_{h.t} =$ **1.000**
Bending stress re-distribution factor - cl.6.1.6(2);	$k_m =$ **0.700**
Crack factor for shear resistance - cl.6.1.7(2);	$k_{cr} =$ **0.670**
Load configuration factor - exp.6.4;	$k_{c.90} =$ **1.000**
System strength factor - cl.6.6;	$k_{sys} =$ **1.000**
Lateral buckling factor - cl.6.3.3(5);	$k_{crit} =$ **1.000**

Compression perpendicular to the grain - cl.6.1.5

Design compressive stress;	$\sigma_{c.90.d} = R_{C\_max} / (N \times b \times L_b) =$ **1.366** N/mm^2
Design compressive strength;	$f_{c.90.d} = k_{mod} \times k_{sys} \times k_{c.90} \times f_{c.90.k} / \gamma_M =$ **1.538** N/mm^2
	$\sigma_{c.90.d} / f_{c.90.d} =$ **0.888**

PASS - Design compressive strength exceeds design compressive stress at bearing

Biaxial bending - cl 6.1.6

Design bending stress in major (y-y) axis;	$\sigma_{m.y.d} = M \times \cos(\theta) / W_y =$ **5.913** N/mm^2
Design bending stress in minor (z-z) axis;	$\sigma_{m.z.d} = M \times \sin(\theta) / W_z =$ **8.766** N/mm^2
Design bending strength;	$f_{m.d} = k_{h.m} \times k_{mod} \times k_{sys} \times k_{crit} \times f_{m.k} / \gamma_M =$ **14.769** N/mm^2
Combined bending checks - eq.6.11 & eq.6.12;	$\sigma_{m.y.d} / f_{m.d} + k_m \times \sigma_{m.z.d} / f_{m.d} =$ **0.816**
	$k_m \times \sigma_{m.y.d} / f_{m.d} + \sigma_{m.z.d} / f_{m.d} =$ **0.874**

PASS - Design bending strength exceeds design bending stress

Shear - cl.6.1.7

Applied shear stress;	$\tau_d = 3 \times F / (2 \times k_{cr} \times A) =$ **0.645** N/mm^2
Permissible shear stress;	$f_{v.d} = k_{mod} \times k_{sys} \times f_{v.k} / \gamma_M =$ **2.462** N/mm^2
	$\tau_d / f_{v.d} =$ **0.262**

PASS - Design shear strength exceeds design shear stress

Deflection - cl.7.2

Deflection limit;	$\delta_{lim} = \min(14\ mm, 0.004 \times L_{s3}) =$ **14.000** mm
Instantaneous deflection due to permanent load;	$\delta_{instG} =$ **1.127** mm
Final deflection due to permanent load;	$\delta_{finG} = \delta_{instG} \times (1 + k_{def}) =$ **1.803** mm
Instantaneous deflection due to variable load;	$\delta_{instQ} =$ **5.841** mm
Factor for quasi-permanent variable action;	$\psi_2 =$ **0.3**
Final deflection due to variable load;	$\delta_{finQ} = \delta_{instQ} \times (1 + \psi_2 \times k_{def}) =$ **6.892** mm

Total final deflection; $\delta_{fin} = \delta_{finG} + \delta_{finQ} =$ **8.695** mm

$\delta_{fin} / \delta_{lim} =$ **0.621**

PASS - Total final deflection is less than the deflection limit

4.0 CONCLUSIONS

PV System Loadings

From the calculations, we see that the combined system (0.13kN/m2) + snow load (0.53kN/m2) = (0.66kN/m2).

Following a check on the supporting structure (See Section 3.5 – Advanced Structure Check) we can confirm that the supporting structure has the capacity to accept the combined PV System and Snow Loadings.

We are able to confirm these loadings to be acceptable, therefore the proposed solar panels can safely be installed onto the existing roof structure with no strengthening works being required.

Appendix A Photographs

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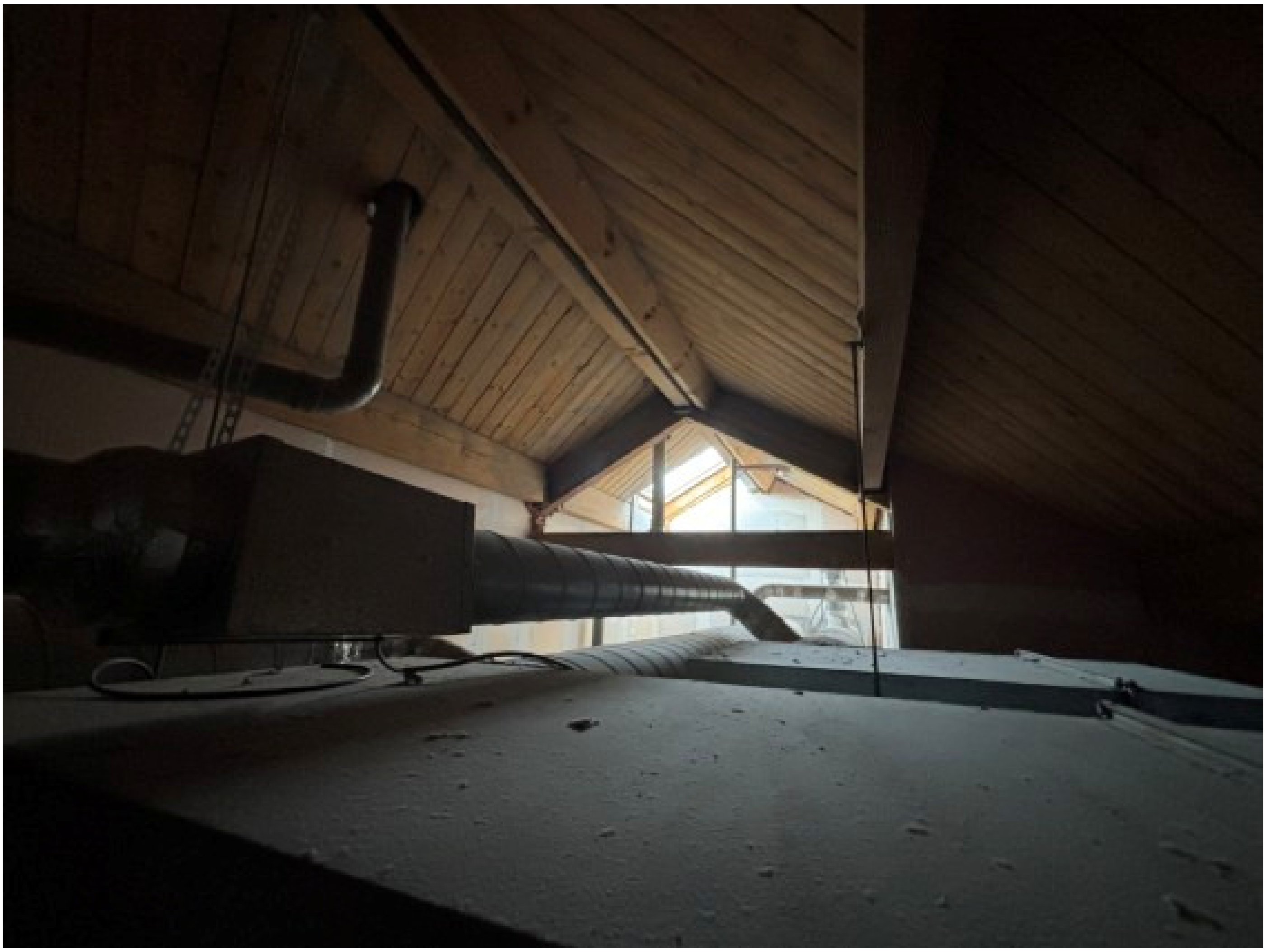

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