Introduction

SylvaGroup Ltd was commissioned to carry out typical calculations to investigate the potential holding down capacity of Solar Limpet roof fixing brackets to a supporting timber roof construction. The Solar Limpet brackets are fixed using proprietary MAGE screws for which the manufacturers have provided fixing data based on test evidence.

Product Description

Injection moulded using DVJ 504-29 UPVC, Solar Limpets are purpose designed, fully adjustable roof fixing brackets.

Solar Limpets are fitted to supporting roof timbers using MAGE screw fixings.

Solar Limpets provide a secure base onto which rails and solar panels can be attached.

Summary of Calculations

Typical calculations have been prepared to consider the fixing capacity of Solar Limpets and compare this with the applied wind loadings for an assumed site location and building shape.

A worst-case arrangement of panel sizes and rail supports was considered in order to establish the maximum likely uplift force to be carried by an individual Solar Limpet. See Figure A1.

The withdrawal capacity of 6.3mm MAGE fixings was provided as 7.0kN (5th percentile characteristic ultimate capacity for 60mm embedment) based on test data. This was cross-checked against calculated withdrawal capacity appropriate for short term (wind) loading. An allowance was made to reduce the MAGE screw capacity to account for non-standard edge distance in the supporting timber members. Two screws were assumed for each Solar Limpet.

Based on these calculations a maximum wind uplift of 2.8kN/m^2 may be carried.

Conclusion

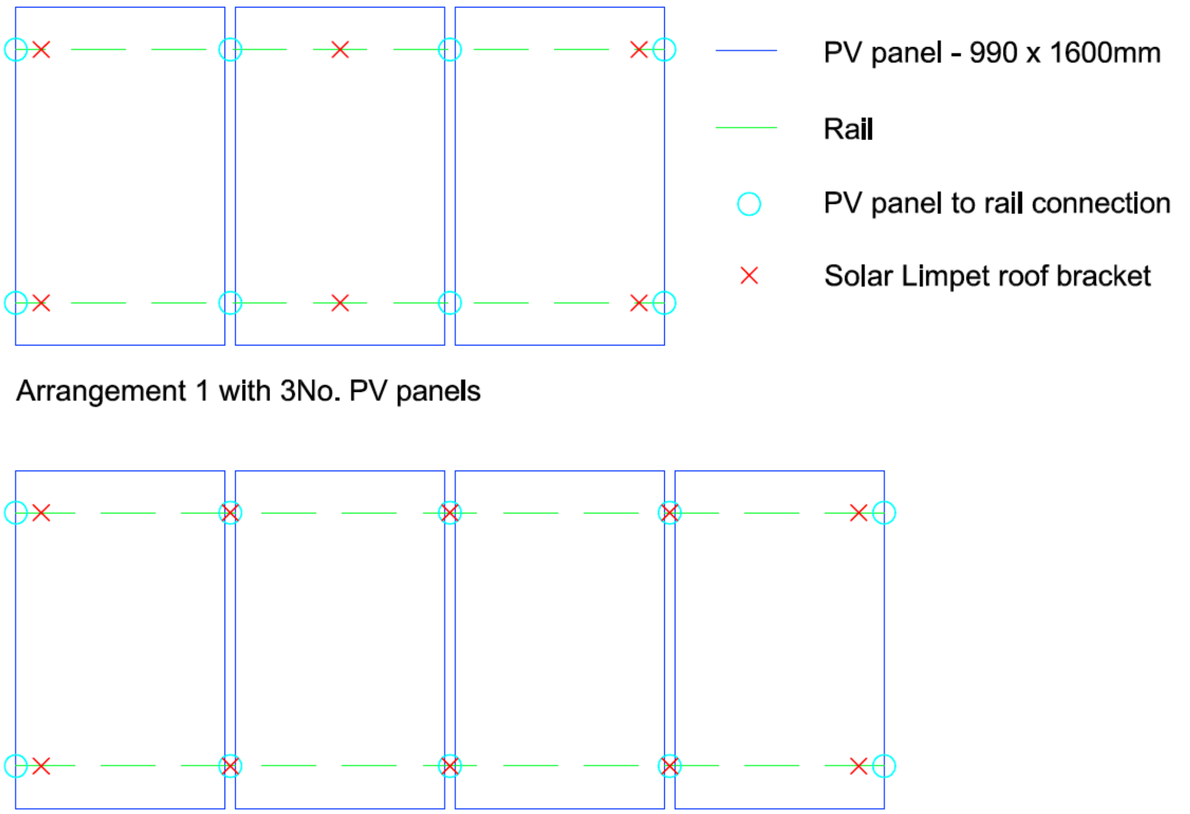
We have considered the connection between the Solar Limpet roof fixing brackets and the underlying roof timbers, fixed using 6.3mm diameter MAGE fixings. Our calculations indicate that the Solar Limpets can be shown to have adequate fixing capacity to the roof structure to resist assumed wind uplift conditions which cover a large proportion of the UK.

Note that we have not reviewed the capacity of fixings between the two parts of the Solar Limpet roof fixing brackets, nor the fixings of the solar panel support rails to the Solar Limpet. These, along with other performance characteristics, are understood to be subject to a testing and assessment programme which is under way with BBA.

The installation of solar panels is considered a material alteration under Building Regulations and requires assessment by a competent person. Structural calculations should be prepared on a site specific basis to determine the number and arrangement of Solar Limpets which will be required for the particular roof construction under consideration.

Appendix A - Structural Calculations

Two arrangements are considered below, which represent typical installation layouts.



Arrangement 2 with 4No. PV panels

Figure A1 Solar Panel Schematic Layout

Each typical PV panel is 990 x 1600mm in size. As such, the wind uplift area per Solar Limpet may be calculated as follows for each arrangement.

Arrangement 1 – wind area per Solar Limpet = 3 (0.99 x 1.6) / 6 = 0.79 m^2/Solar Limpet

Arrangement 2 – wind area per Solar Limpet = 4 (0.99 x 1.6) / 10 = 0.63 m^2/Solar Limpet

Arrangement 1 is most onerous.

Using MAGE test data

Ultimate withdrawal capacity, $F_{ult,k}$ = 7.0 kN for 6.5mm dia. with 60mm embedment in C16 timber. See Appendix B for MAGE data sheet 7641 and analysis of test data.

Using established spacing rules, a 6.5mm diameter screw should be placed no closer than 32.5mm from the edge of the timber being fixed, or an overall rafter width of 65mm. However typical roof timbers in the UK will be between 35mm and 50mm.

It is prudent therefore to apply a pro-rata reduction to the withdrawal value to account for reduced edge distance and potential inaccuracy of installation on narrow members.

Edge distance reduction = 35/65 = 0.54

Applying partial factors to account for duration of load, moisture content and safety gives,
$F_d = (F_{ult,k}.k_{mod})/\ \gamma_m$ = (7.0*0.54*0.9)/1.3 = 2.6 kN (short term, service class 1 & 2)

Using load partial factor of γ_Q=1.5 for variable actions, the maximum design wind uplift may be calculated as follows, assuming 2 MAGE screws per bracket.

Maximum design wind uplift = (2*2.6)/(1.5*0.79) = 4.4 kN/m^2

Using Eurocode 5 design approach

Calculated withdrawal capacity for 6.5mm dia. x 80mm long, 74mm embedment in C16 timber = 3083 N (very short term, service class 1 & 2).

Apply edge distance reduction factor = 0.54

The maximum design wind uplift may be calculated as follows, assuming 2 MAGE screws per bracket.

Maximum wind uplift = (2*3083*0.54)/(1.5*0.79*1000) = 2.8 kN/m^2

Summary of wind loading (See Appendix C for full calculations)

Site location:	Aberdeen
Building length:	20m
Building width:	10m
Height to eaves:	10m
Roof type:	20 degree duo pitch

The maximum wind uplift was calculated as 2.73kN/m^2 (local zone “G” at the edge of the roof area).

Appendix B

MAGE Data Sheet

the fastening connection

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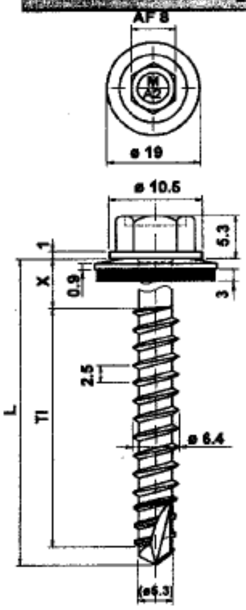
Technical performance [illegible]



MAGE TOPEX STAINLESS STEEL 7641 Ø 6.5 mm

Fastener Material : 1.4301 Stainless Steel A2 (304G 5 N AISI 304)

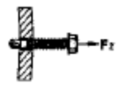
Washer Material : Stainless Steel A2 (304 grade), EPDM bonded.

Drill Point : Fully Hardened Stainless Steel (for fastening steel thickness max. 0.8 mm. to timber.)

Diameter : HIGH - THREAD Ø 6,5 mm.

REMARKS:
Look out speed Max. 1'300 rpm
Steel Quality ≤ 3 mm. S 280 GD (Dx51D) 270 – 500 N / mm^2

Pull-out load F_Z in N



30 mm. thread into timber	5'572 N	

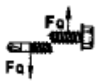
Pull-over load F_U in N

Steel S 280 GD (Dx51D) in mm.	0,4	0,5	0,63	0,75	0,88
Washer dia. 16 mm. Stainless steel	3595	5090	5430	6440	7530
Washer dia. 19 mm. Stainless steel	3950	5600	6640	7720	9020

Tensile breaking load Z_B in Kn

14,83 Kn

Sheer breaking load F_Q in Kn



12,86 Kn

Torsional strength in Nm 15 Nm

All values mentioned below are ultimate failure loads and do not contain any safety factors

<u>MAGE Test Data Analysis</u>

Indicative tests were conducted on samples of 35 x 100mm C16 timber to establish: -

- the ability of the MAGE screw to be driven in to the narrow edge without splitting the timber and
- establish ultimate withdrawal capacity for 60mm embedment.

The tests were conducted using a calibrated loadcell suitable for a range of 0 to 20 kN.

Test Arrangement & Apparatus

Screw driven home

Withdrawal test in apparatus

Pull-out test results

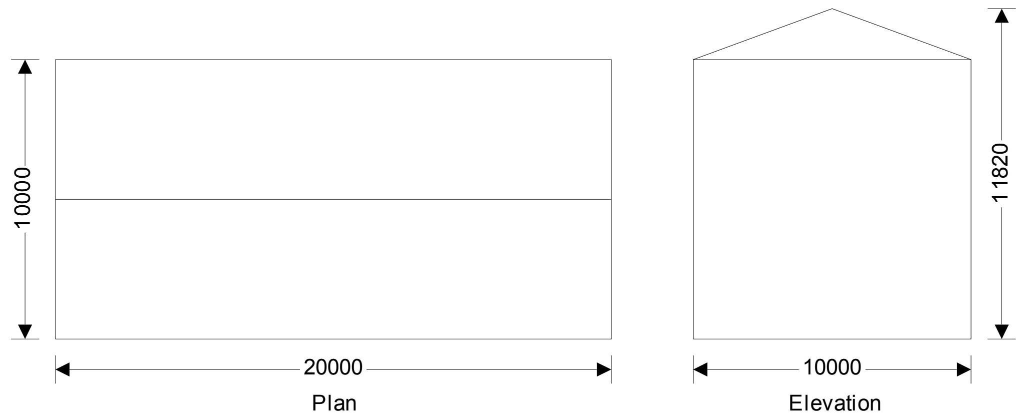
Type	7641 - 6.5mm diameter x 90mm long
Embedment	60mm
Timber	100 x 35 mm C16

Test No	F_{ult} (kN)
1	7.7
2	7.8
3	7.4
4	7.6
5	7.2
6	7.3
mean	7.50
SD	0.24
$F_{ult,k}$ (kN)	7.00
k_n	2.13

Appendix C – Wind Loading Calculations

WIND LOADING (EN1991-1-4)

TEDDS calculation version 3.0.09



Building data

Type of roof	Duopitch
Length of building	L = **20000** mm
Width of building	W = **10000** mm
Height to eaves	H = **10000** mm
Pitch of roof	α_0 = **20.0** deg
Total height	h = **11820** mm

Basic values

Location	Aberdeen
Wind speed velocity (FigureNA.1)	$v_{b,map}$ = **25.7** m/s
Distance to shore	L_{shore} = **3.50** km
Altitude above sea level	A_{alt} = **61.0**m
Altitude factor	$c_{alt} = A_{alt} \times 0.001m^{-1} + 1$ = **1.061**
Fundamental basic wind velocity	$v_{b,0} = v_{b,map} \times c_{alt}$ = **27.3** 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**
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)	$v_b = c_{dir} \times c_{season} \times v_{b,0} \times c_{prob}$ = **27.3** m/s
Reference mean velocity pressure	$q_b = 0.5 \times \rho \times v_b^2$ = **0.456** kN/m^2

Orography

Type of feature	Cliffs and escarpments
Actual length of upwind slope in wind direction	L_u = **50000** mm
Effective height of feature	Z = **20000** mm
Upwind slope in upwind direction	$\varphi = Z / L_u$ = **0.40**
Effective length of upwind slope (Table A.2)	$L_e = Z / 0.3$ = **66667** mm
Horiz distance of the site from the top of the crest	x = **-5000** mm
Terrain category	Sea
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 2 parts as the height h is greater than b but less than 2b (cl.7.2.2)

Peak velocity pressure - windward wall - Wind 0 deg and roof

Reference height (at which q is sought)	z = **10000**mm
Displacement height (sheltering effects excluded)	h_{dis} = **0** mm
Orographic location factor (Figure A.2)	s = **0.60**
Orography factor	c_o = 1 + 0.6 × s = **1.36**
Exposure factor (Figure NA.7)	c_e = **2.59**
Peak velocity pressure	$q_p = c_e \times ((c_o + 0.6) / 1.6)^2 \times q_b$ = **1.77** kN/m^2

Structural factor

Structural damping	δ_s = **0.100**
Height of element	h_{part} = **10000** mm
Size factor (Table NA.3)	c_s = **0.91**
Dynamic factor (Figure NA.9)	c_d = **1.02**
Structural factor	$c_sc_d = c_s \times c_d$ = **0.927**

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

Reference height (at which q is sought)	z = **10000**mm
Displacement height (sheltering effects excluded)	h_{dis} = **0** mm
Orographic location factor (Figure A.2)	s = **0.60**
Orography factor	c_o = 1 + 0.6 × s = **1.36**
Exposure factor (Figure NA.7)	c_e = **2.59**
Peak velocity pressure	$q_p = c_e \times ((c_o + 0.6) / 1.6)^2 \times q_b$ = **1.77** kN/m^2

Structural factor

Structural damping	δ_s = **0.100**
Height of element	h_{part} = **10000** mm
Size factor (Table NA.3)	c_s = **0.92**
Dynamic factor (Figure NA.9)	c_d = **1.04**
Structural factor	$c_sc_d = c_s \times c_d$ = **0.952**

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

Reference height (at which q is sought)	z = **11820**mm
Displacement height (sheltering effects excluded)	h_{dis} = **0** mm
Orographic location factor (Figure A.2)	s = **0.57**
Orography factor	c_o = 1 + 0.6 × s = **1.34**
Exposure factor (Figure NA.7)	c_e = **2.71**
Peak velocity pressure	$q_p = c_e \times ((c_o + 0.6) / 1.6)^2 \times q_b$ = **1.82** kN/m^2

Structural factor

Structural damping	δ_s = **0.100**
Height of element	h_{part} = **1820** mm
Size factor (Table NA.3)	c_s = **0.95**
Dynamic factor (Figure NA.9)	c_d = **1.04**
Structural factor	$c_sc_d = c_s \times c_d$ = **0.979**

Structural factor

Structural damping	δ_s = **0.100**
Height of element	h_{part} = **11820** mm

Size factor (Table NA.3) c_s = **0.92**

Dynamic factor (Figure NA.9) c_d = **1.04**

Structural factor $c_sc_d = c_s \times c_d$ = **0.952**

Structural factor - roof 0 deg

Structural damping δ_s = **0.100**

Height of element h_{part} = **11820** mm

Size factor (Table NA.3) c_s = **0.91**

Dynamic factor (Figure NA.9) c_d = **1.02**

Structural factor $c_sc_d = c_s \times c_d$ = **0.925**

Peak velocity pressure for internal pressure

Peak velocity pressure – internal (as roof press.) $q_{p,i}$ = **1.82** 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)	-0.90	1.82	-1.87	21.28	-39.89
G (-ve)	-0.70	1.82	-1.54	21.28	-32.74
H (-ve)	-0.33	1.82	-0.92	63.85	-58.92
I (-ve)	-0.50	1.82	-1.20	63.85	-76.78
J (-ve)	-1.17	1.82	-2.32	42.57	-98.83

Total vertical net force $F_{w,v}$ = **-288.64** kN

Total horizontal net force $F_{w,h}$ = **15.07** 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	1.82	-2.38	42.91	-102.21
B	-0.80	1.82	-1.71	66.19	-113.11
D	0.80	1.95	1.08	200.00	216.65
E	-0.51	1.95	-1.28	200.00	-256.71

Overall loading

Equiv leeward net force for overall section $F_l = F_{w,wE}$ = **-256.7** kN

Net windward force for overall section $F_w = F_{w,wD}$ = **216.6** kN

Lack of correlation (cl.7.2.2(3) – Note) f_{corr} = **0.86** as h/W is 1.182

Overall loading overall section $F_{w,D} = f_{corr} \times (F_w - F_l + F_{w,h})$ = **418.5** kN

Roof load case 2 - 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)	-1.47	1.82	-2.90	5.32	-15.43
G (-ve)	-1.37	1.82	-2.73	5.32	-14.51

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)	-1.47	1.82	-2.90	5.32	-15.43
G (-ve)	-1.37	1.82	-2.73	5.32	-14.51
H (-ve)	-0.60	1.82	-1.40	42.57	-59.62
I (-ve)	-0.43	1.82	-1.11	159.63	-177.57

Total vertical net force $F_{w,v}$ = **-251.02** kN

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

Walls load case 2 - 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	1.95	-2.59	20.00	-51.86
B	-0.80	1.95	-1.85	80.00	-147.99
C	-0.50	1.95	-1.29	100.00	-129.23
D_b	0.75	1.77	0.89	100.00	89.07
D_u	0.75	1.82	0.96	9.10	8.75
E	-0.39	1.82	-1.04	109.10	-113.37

Overall loading

Equiv leeward net force for upper section $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wu}$ = **-9.5** kN

Net windward force for upper section $F_w = F_{w,wu}$ = **8.8** kN

Lack of correlation (cl.7.2.2(3) – Note) f_{corr} = **0.85** as h/L is 0.591

Overall loading upper section $F_{w,u} = f_{corr} \times (F_w - F_l + F_{w,h})$ = **15.5** kN

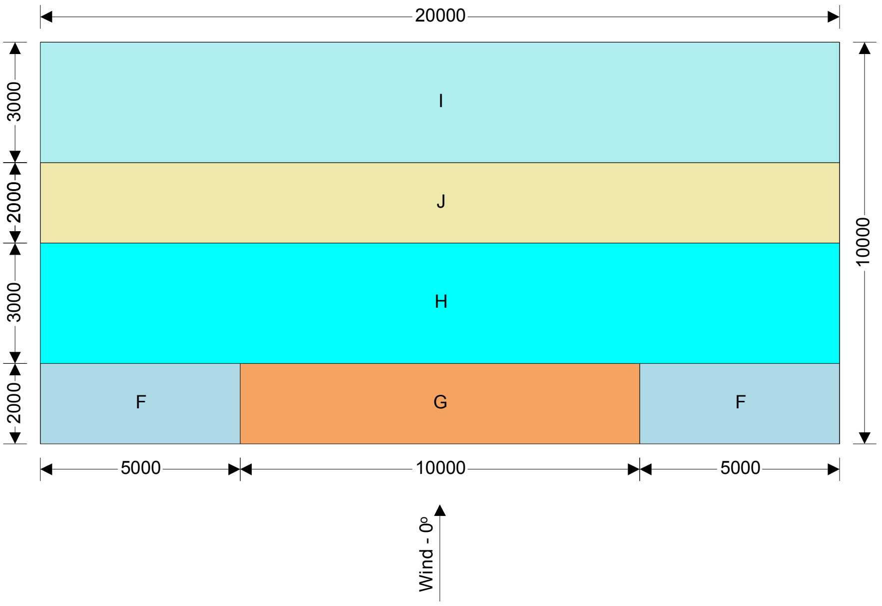
Equiv leeward net force for bottom section $F_l = F_{w,wE} / A_{ref,wE} \times A_{ref,wb}$ = **-103.9** kN

Net windward force for bottom section $F_w = F_{w,wb}$ = **89.1** kN

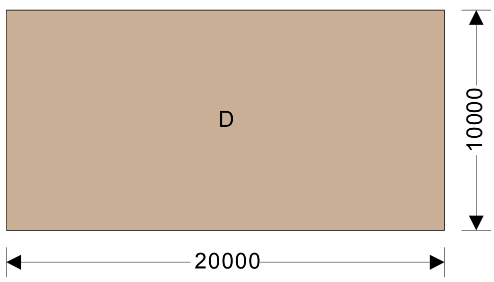
Lack of correlation (cl.7.2.2(3) – Note) f_{corr} = **0.85** as h/L is 0.591

Overall loading bottom section $F_{w,b} = f_{corr} \times (F_w - F_l)$ = **164.0** kN

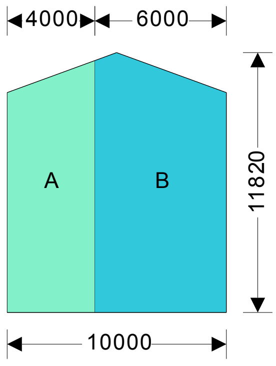
Project				Job no.	
Solar Limpet				10120	
Calcs for				Start page no./Revision	
Wind loading example				5	
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
JRC	04/03/2012	SE	29/02/2012		



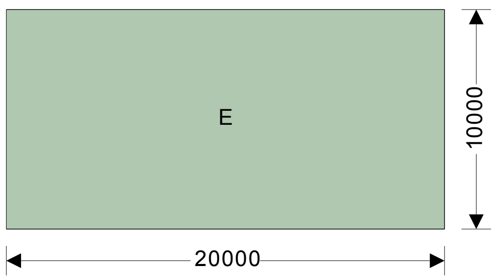
Plan view - Duopitch roof



Windward face

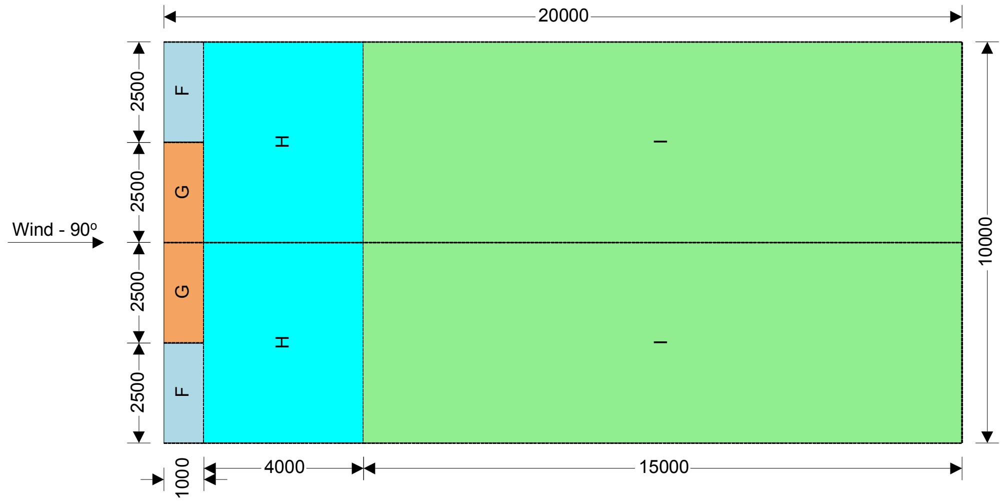


Side face

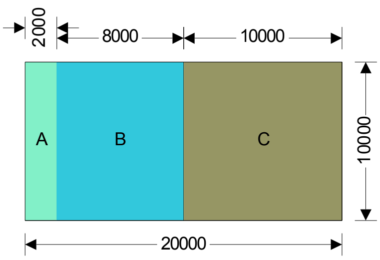


Leeward face

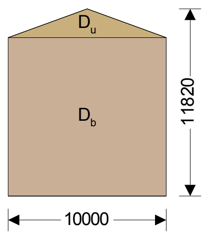
SYLVA GROUP	Project Solar Limpet				Job no. 10120	
	Calcs for Wind loading example				Start page no./Revision 6	
	Calcs by JRC	Calcs date 04/03/2012	Checked by SE	Checked date 29/02/2012	Approved by	Approved date



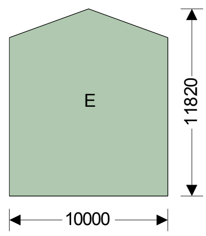
Plan view - Duopitch roof



Side face



Windward face



Leeward face