10 Almsford Road

Harrogate

North Yorkshire

HG2 8EQ

Tel: 07749 838310

Email: tim@hdesignsltd.co.uk

NYMNPA

13/12/2023

DESIGN CALCULATIONS

FOR

THORPE HALL, FYLINGTHORPE

PV Roof Assessment

Client:	**Wigwam Ltd**				
Date:	**28/11/2023**	**Prepared by:**	**Timothy Hunt**	**Job Ref:**	**23/0510**

H DESIGNS LTD
10 Almsford Road
Harrogate
North Yorkshire
HG2 8EQ
Tel: 07749 838310
Email: tim@hdesignsltd.co.uk

Scheme	Job Ref.
Thorpe Hall, Fylingthorpe	23/0510
Job	**Sheet no./rev.**
PV Roof Assessment	1
Calc. by	**Date**
Timothy Hunt	28/11/2023

CONTENTS

10 Almsford Road
Harrogate
North Yorkshire
HG2 8EQ
Tel: 07749 838310
Email: tim@hdesignsltd.co.uk

Scheme	Job Ref.
Thorpe Hall, Fylingthorpe	23/0510
Job	**Sheet no./rev.**
PV Roof Assessment	2
Calc. by	**Date**
Timothy Hunt	28/11/2023

Designer's Risk Assessment

Duration of Risk	Description	ID Letter	Source of Hazard	ID Number	Persons at Risk
Design.	Risk is present during design phase of scheme	A	Chemicals / C.O.S.H.H	1	Site Worker
		B	Collision / Impact		
		C	Competence	2	Site Visitor
Const.	Risk is present during construction phase of scheme	D	Components and Materials		
		E	Confined Space	3	General Public
		F	Electricity		
Maint.	Risk is present during maintenance of scheme	G	Environmental Conditions		
		H	Erection		
		J	Falls from Height		
Demol.	Risk is present during demolition of scheme	K	Foundations		
		L	General Use		
		M	Heat / Fire / Explosions		
		N	Manual Handling		
		O	Misuse / Vandalism		
		P	Noise		
		Q	Obstruction		
		R	Other		
		S	Rotation / Overturning		
		T	Traffic (Rail/Road)		
		U	Use of Plant / Machinery		
		V	Vibration		
		W	Welfare / First Aid		

General

Duration	Type	Hazard	Person at Risk	Residual Hazard Eliminated/Reduced by (Design)	Residual Hazard Control Measures On Site
Design /Const.	A	Site Conditions Unknown materials on site	1, 2	Site to be surveyed before commencement of work to identify hazards that can be seen.	Excavations are to be supervised to ensure that no hazards/services are disturbed.
Design	C	Workers undertaking tasks they are not trained to carry out	1, 2, 3	All site personnel are to carry industry recognised cards showing their skills. Site personnel to read method statements/work measurements before commencing work and sign off their competency.	Industry recognised training to be undertaken and all works to be undertaken by trained personnel.
Design	D,F	Site has not been surveyed before design for services	1	-	Site to be surveyed for services which are to be marked on site and on a drawing before work commences. Where on site markings are lost these are to be replaced.
Const.	W	Cuts from sharp objects	1, 2	-	Good housekeeping maintained on site PPE to be worn at all times First aid kit accessible at all times Suitable number of workers to be trained in first aid
Const.	W	Slips and trips	1, 2	-	Good housekeeping maintained on site Clearly designated walkways Avoid change of levels/ use ramps Reduce slippery surfaces using grit (for ice) or stones (for mud) PPE to be worn at all times First aid kit accessible at all times Suitable number of workers to be trained in first aid
Const.	T	Injury caused by moving vehicles on site	1, 2	-	Clear routes identified for site vehicles High visibility jackets to be worn at all times Provide parking for workforce and visitors away from working area
Const.	P	Noise	1, 2, 3	-	Assess construction techniques for excessive noise and reduce where possible Ear defenders should be worn by those exposed to excessive noise
Const.	M	Fire/explosion	1, 2, 3	-	Good housekeeping maintained on site Fire extinguishers available

Const.	O	Site vandalism	1, 2, 3	-	Secure site boundary Use appropriate signage

Beams/Roof/Masonry

Duration	Type	Hazard	Person at Risk	Residual Hazard Eliminated/Reduced by (Design)	Residual Hazard Control Measures On Site
Const.	J	Falls from height	1, 2	-	Use lifting platforms where possible Ladders to be in good condition secured correctly Correct scaffolding to be provided and inspected Trained personnel only to use scaffold
Const.	W	Injury from falling objects	1, 2	-	Works to be programmed to keep safe zones clear beneath workers overhead PPE to be worn at all time Waste materials removed
Const.	N	Manual handling of masonry	1	All blocks specified less than 20kg therefore no special lifting arrangements required	Provisions to be made for mechanical lifting where masonry loads are over 20kg
Const.	N	Manual handling of beams/lintels	1	Heavy beams/lintels avoided where possible	Provisions to be made for mechanical lifting where required for large beams & columns
Const.	D	Contact with mortar	1	-	Gloves to be worn when handling mortar Washing facilities to be provided
Const.	W	Tripping/injury arising from opening up works	1, 2	-	Cover opening up works Use appropriate signage/barriers
Const.	R	Instability of structure during modifications	1, 2	All information/drawings provided used to assess existing load paths and supports	Use suitable temporary support Carry out structural survey if required
Demol.	R	Instability of structure during demolition	1, 2	Provide as built information as requested	Carry out structural survey if required Method statement for demolition prepared

These calculations are to check the capacity of the existing roof to support the new PV panels installed onto the roof. The existing house is constructed from masonry and timber trusses.

GENERAL LOADINGS

ROOF LOADING (PITCHED TILED ROOF)

Roof slope θ = **42.0** °

Dead load

Tiles — $Roof_{D1}$ = **0.45** kN/m^2

Battens — $Roof_{D2}$ = **0.05** kN/m^2

Felt — $Roof_{D3}$ = **0.05** kN/m^2

Rafters — $Roof_{D4}$ = **0.10** kN/m^2

Dead load on slope — $Roof_{DL\_sroof}$ = sum($Roof_{D1}$,$Roof_{D2}$,$Roof_{D3}$,$Roof_{D4}$) = **0.65** kN/m^2

Ceiling joists — $Roof_{D5}$ = **0.05** kN/m^2

Insulation — $Roof_{D6}$ = **0.05** kN/m^2

Plasterboard and skim — $Roof_{D7}$ = **0.14** kN/m^2

Services — $Roof_{D8}$ = **0.05** kN/m^2

Dead load on plan — $Roof_{DL\_proof}$ = sum($Roof_{D5}$,$Roof_{D6}$,$Roof_{D7}$,$Roof_{D8}$) = **0.29** kN/m^2

Total dead load on plan — $Roof_{DL}$ = $Roof_{DL\_sroof}$ / cos(θ) + $Roof_{DL\_proof}$= **1.16** kN/m^2

Imposed load

Roof imposed load — $Roof_{IL}$ = **0.75** kN/m^2 on plan

Total roof loads

Unfactored foundation design loads — w_{roof_u} = $Roof_{DL}$ + $Roof_{IL}$ = **1.91** kN/m^2

Factored design loads — w_{roof_f} = 1.4 × $Roof_{DL}$ + 1.6 × $Roof_{IL}$ = **2.83** kN/m^2

SOLAR PANEL LOADING

Dead load

Total load of new Panel — W_{Pan_DL} = 21.8 kg × g_{acc} × 4 = **0.86** kN

Area of new panels — A_{Pan} = 1.762m × 1.134m × 4 = **7.99** m^2

Solar panel dead load — $Panel_{DL}$ = W_{Pan_DL} / A_{Pan} = **0.11** kN/m^2

Framework for panels (generally) — $Frame_{DL}$ = 4.0 kg/m^2 × g_{acc} = **0.04** kN/m^2

Total panel loads

Unfactored foundation design loads — w_{panel_u} = $Panel_{DL}$ + $Frame_{DL}$ = **0.15** kN/m^2

Factored design loads — w_{panel_f} = 1.4 × ($Panel_{DL}$ + $Frame_{DL}$) = **0.20** kN/m^2

SNOW LOADING TO BS6399:PART 3:1988

TEDDS calculation version 1.0.03

Site location

Location of site — **York**

Site altitude — A = **95** m

Calculate site snow load

From BS6399:Part 3: 1988 - Figure 1. Basic snow load on the ground

Basic snow load — s_b = **0.60** kN/m^2

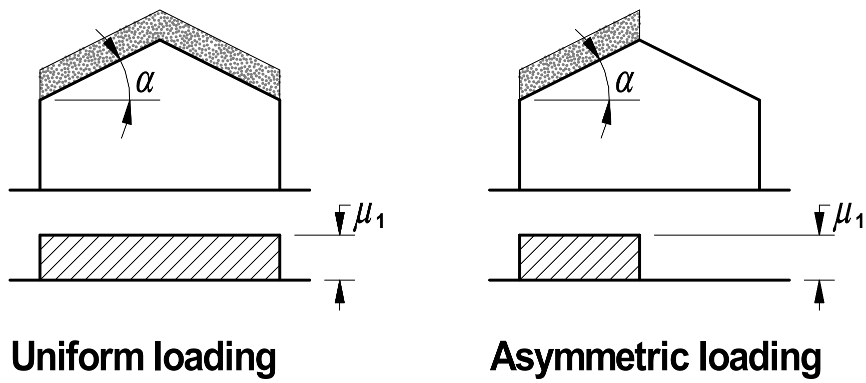
s_{alt} = 0.1 × s_b + (0.09 kN/m^2) = **0.15** kN/m^2

H DESIGNS LTD
10 Almsford Road
Harrogate
North Yorkshire
HG2 8EQ
Tel: 07749 838310
Email: tim@hdesignsltd.co.uk

Scheme	Job Ref.
Thorpe Hall, Fylingthorpe	23/0510
Job	Sheet no./rev.
PV Roof Assessment	6
Calc. by	Date
Timothy Hunt	28/11/2023

Site snow load $s_0 = \max(s_b, s_b + s_{alt} \times (A - (100\ m)) / 100\ m) = \mathbf{0.60}\ kN/m^2$

BS6399:Part3:1988 Cl.6.2



Roof geometry

Roof type **Pitched**

Distance on plan from gutter to ridge $b = \mathbf{2.380}$ m

Angle of pitch of roof $\alpha = \mathbf{42.0}$ deg

Calculate uniform snow load

From BS6399:Part 3: 1988 - Figure 3. Snow load shape coefficients for pitched roofs

Snow load shape coefficient $\mu_1 = 0.8 \times [(60\ deg - \alpha) / 30\ deg] = \mathbf{0.48}$

Uniform roof snow load $s_{d1} = \mu_1 \times s_0 = \mathbf{0.29}\ kN/m^2$

BS6399:Part3:1988 Cl.5

Calculate asymmetric snow load

From BS6399:Part 3: 1988 - Figure 3. Snow load shape coefficients for pitched roofs

Snow load shape coefficient $\mu_1 = 1.2 \times [(60\ deg - \alpha) / 30\ deg] = \mathbf{0.72}$

Asymmetric roof snow load $s_{d1} = \mu_1 \times s_0 = \mathbf{0.43}\ kN/m^2$

BS6399:Part3:1988 Cl.5

Snow sliding down roof

Maximum uniform snow load on roof $s_{d\_max} = \mathbf{0.43}\ kN/m^2$

Force from sliding snow load $F_s = s_{d\_max} \times b \times \sin(\alpha) = \mathbf{0.69}\ kN/m$

BS6399:Part3:1988 Cl.8

Load on Portal

From Roof $W_{Roof\_u} = w_{roof\_u} = \mathbf{1.91}\ kN/m^2$

From Snow $W_{Roof\_SL} = s_{d\_max} = \mathbf{0.43}\ kN/m^2$

From Panels $W_{Panel\_u} = w_{panel\_u} = \mathbf{0.15}\ kN/m^2$

LOAD ASSESSMENT

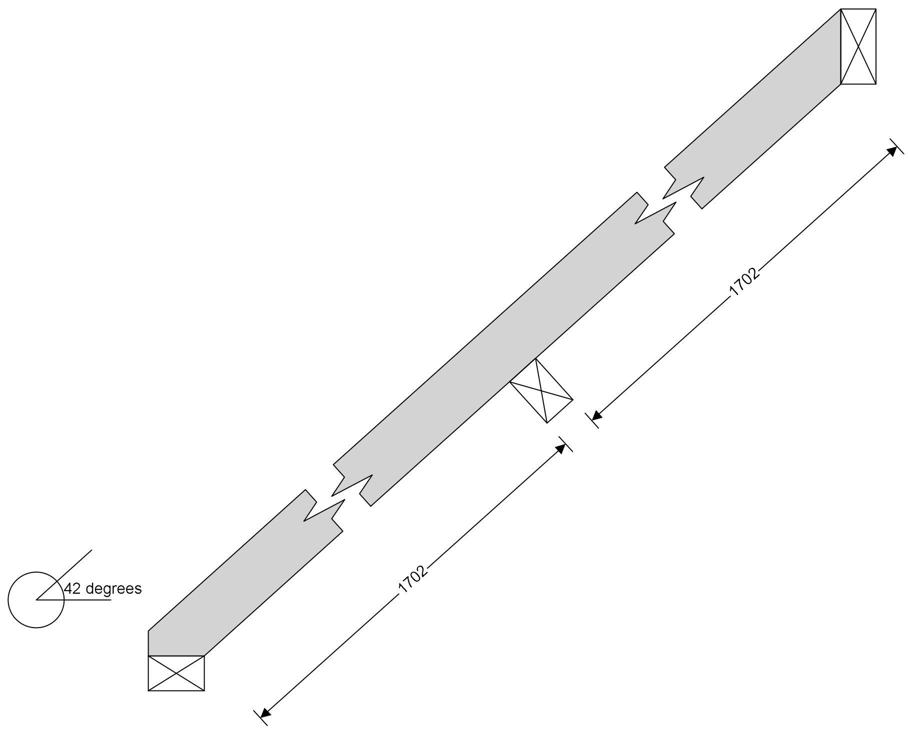
Percentage increase in loading on trusses $P = W_{Panel\_u} / (W_{Roof\_u} + W_{Roof\_SL}) = \mathbf{6.23}\ \%$

The LABC guidance note for retrofitting solar panels recommends that they are only classed as a material alteration to a building if the load on the roof is increased by more than 15%. As this is not the case further design checks are not required.

SECONDARY CHECK - TIMBER RAFTER DESIGN (BS5268)

TIMBER RAFTER DESIGN (BS5268-2:2002)

TEDDS calculation version 1.0.03



Rafter details

Breadth of timber sections	b = **47** mm
Depth of timber sections	h = **75** mm
Rafter spacing	s = **350** mm
Rafter slope	α = **42.0** deg
Clear span of rafter on horizontal	L_{clh} = **1265** mm
Clear span of rafter on slope	$L_{cl} = L_{clh} / \cos(\alpha)$ = **1702** mm
Rafter span	**Continuous**
Timber strength class	**C16**

Section properties

Cross sectional area of rafter	$A = b \times h$ = **3525** mm^2
Section modulus	$Z = b \times h^2 / 6$ = **44063** mm^3
Second moment of area	$I = b \times h^3 / 12$ = **1652344** mm^4
Radius of gyration	$r = \sqrt{(I / A)}$ = **21.7** mm

Loading details

Rafter self weight	$F_j = b \times h \times \rho_{char} \times g_{acc}$ = **0.01** kN/m
Dead load on slope	F_d = **0.80** kN/m^2

Imposed load on plan F_u = **0.75** kN/m^2

Imposed point load F_p = **0.90** kN

Modification factors

Section depth factor $K_7 = (300\text{ mm} / h)^{0.11}$ = **1.16**

Load sharing factor K_8 = **1.10**

<u>Consider long term load condition</u>

Load duration factor K_3 = **1.00**

Total UDL perpendicular to rafter $F = F_d$ ´ $\cos(\alpha)$ ´ $s + F_j$ ´ $\cos(\alpha)$ = **0.216** kN/m

Notional bearing length $L_b = F \times L_{cl} / [2 \times (b \times \sigma_{cp1} \times K_8 - F)]$ = **2** mm

Effective span $L_{eff} = L_{cl} + L_b$ = **1704** mm

Check bending stress at purlin

Bending stress parallel to grain σ_m = **5.300** N/mm^2

Permissible bending stress $\sigma_{m\_adm} = \sigma_m \times K_3 \times K_7 \times K_8$ = **6.790** N/mm^2

Applied bending stress $\sigma_{m\_max} = F$ ´ $L_{eff}^2 / (8$ ´ $Z)$ = **1.779** N/mm^2

PASS - Applied bending stress within permissible limits

Check compressive stress parallel to grain at purlin

Compression stress parallel to grain σ_c = **6.800** N/mm^2

Minimum modulus of elasticity E_{min} = **5800** N/mm^2

Compression member factor K_{12} = **0.52**

Permissible compressive stress $\sigma_{c\_adm} = \sigma_c \times K_3 \times K_8 \times K_{12}$ = **3.889** N/mm^2

Applied compressive stress $\sigma_{c\_max} = 3$ ´ F ´ L_{eff} ´ $(\cot(\alpha) + 8$ ´ $\tan(\alpha) / 3) / (8$ ´ $A)$ = **0.138** N/mm^2

PASS - Applied compressive stress within permissible limits

Check combined bending and compressive stress parallel to grain at purlin

Euler stress $\sigma_e = \pi^2 \times E_{min} / \lambda^2$ = **9.243** N/mm^2

Euler coefficient $K_{eu} = 1 - (1.5 \times \sigma_{c\_max} \times K_{12} / \sigma_e)$ = **0.988**

Combined axial compression and bending check $\sigma_{m\_max} / (\sigma_{m\_adm} \times K_{eu}) + \sigma_{c\_max} / \sigma_{c\_adm}$ = **0.300 < 1**

PASS - Combined compressive and bending stresses are within permissible limits

Check bending stress in lower portion of rafter

Bending stress parallel to grain σ_m = **5.300** N/mm^2

Permissible bending stress $\sigma_{m\_adm} = \sigma_m \times K_3 \times K_7 \times K_8$ = **6.790** N/mm^2

Applied bending stress $\sigma_{m\_max} = 9$ ´ F ´ $L_{eff}^2 / (128$ ´ $Z)$ = **1.001** N/mm^2

PASS - Applied bending stress within permissible limits

Check compressive stress parallel to grain in lower portion of rafter

Compression stress parallel to grain σ_c = **6.800** N/mm^2

Minimum modulus of elasticity E_{min} = **5800** N/mm^2

Compression member factor K_{12} = **0.52**

Permissible compressive stress $\sigma_{c\_adm} = \sigma_c \times K_3 \times K_8 \times K_{12}$ = **3.889** N/mm^2

Applied compressive stress $\sigma_{c\_max} = 3$ ´ F ´ L_{eff} ´ $(\cot(\alpha) + 13$ ´ $\tan(\alpha) / 3) / (8$ ´ $A)$ = **0.196** N/mm^2

PASS - Applied compressive stress within permissible limits

Check combined bending and compressive stress parallel to grain in lower portion of rafter

Euler stress $\sigma_e = \pi^2 \times E_{min} / \lambda^2$ = **9.243** N/mm^2

10 Almsford Road
Harrogate
North Yorkshire
HG2 8EQ
Tel: 07749 838310
Email: tim@hdesignsltd.co.uk

Euler coefficient	$K_{eu} = 1 – (1.5 \times \sigma_{c\_max} \times K_{12} / \sigma_e) =$ **0.983**
Combined axial compression and bending check	$\sigma_{m\_max} / (\sigma_{m\_adm} \times K_{eu}) + \sigma_{c\_max} / \sigma_{c\_adm} =$ **0.200 < 1**

PASS - Combined compressive and bending stresses are within permissible limits

Check shear stress

Shear stress parallel to grain	$\tau =$ **0.670** N/mm^2
Permissible shear stress	$\tau_{adm} = \tau \times K_3 \times K_8 =$ **0.737** N/mm^2
Applied shear stress	τ_{max} = 15 ´ F ´ L_{eff} / (16 ´ A) = **0.098** N/mm^2

PASS - Applied shear stress within permissible limits

Check deflection

Permissible deflection	$\delta_{adm} = 0.003 \times L_{eff} =$ **5.112** mm
Bending deflection	δ_b = F ´ L_{eff}^4 / (185 ´ E_{mean} ´ I) = **0.677** mm
Shear deflection	δ_s = 12 ´ F ´ L_{eff}^2 / (5 ´ E_{mean} ´ A) = **0.049** mm
Total deflection	$\delta_{max} = \delta_b + \delta_s =$ **0.725** mm

PASS - Total deflection within permissible limits

<u>Consider medium term load condition</u>

Load duration factor	$K_3 =$ **1.25**
Total UDL perpendicular to rafter	F = [F_u ´ cos(α)^2 + F_d ´ cos(α)] ´ s + F_j ´ cos(α) = **0.361** kN/m
Notional bearing length	$L_b = F \times L_{cl} / [2 \times (b \times \sigma_{cp1} \times K_8 - F)] =$ **3** mm
Effective span	$L_{eff} = L_{cl} + L_b =$ **1705** mm

Check bending stress at purlin

Bending stress parallel to grain	$\sigma_m =$ **5.300** N/mm^2
Permissible bending stress	$\sigma_{m\_adm} = \sigma_m \times K_3 \times K_7 \times K_8 =$ **8.488** N/mm^2
Applied bending stress	σ_{m_max} = F ´ L_{eff}^2 / (8 ´ Z) = **2.977** N/mm^2

PASS - Applied bending stress within permissible limits

Check compressive stress parallel to grain at purlin

Compression stress parallel to grain	$\sigma_c =$ **6.800** N/mm^2
Minimum modulus of elasticity	$E_{min} =$ **5800** N/mm^2
Compression member factor	$K_{12} =$ **0.47**
Permissible compressive stress	$\sigma_{c\_adm} = \sigma_c \times K_3 \times K_8 \times K_{12} =$ **4.400** N/mm^2
Applied compressive stress	σ_{c_max} = 3 ´ F ´ L_{eff} ´ (cot(α) + 8 ´ tan(α) / 3) / (8 ´ A) = **0.230** N/mm^2

PASS - Applied compressive stress within permissible limits

Check combined bending and compressive stress parallel to grain at purlin

Euler stress	$\sigma_e = \pi^2 \times E_{min} / \lambda^2 =$ **9.231** N/mm^2
Euler coefficient	$K_{eu} = 1 – (1.5 \times \sigma_{c\_max} \times K_{12} / \sigma_e) =$ **0.982**
Combined axial compression and bending check	$\sigma_{m\_max} / (\sigma_{m\_adm} \times K_{eu}) + \sigma_{c\_max} / \sigma_{c\_adm} =$ **0.409 < 1**

PASS - Combined compressive and bending stresses are within permissible limits

Check bending stress in lower portion of rafter

Bending stress parallel to grain	$\sigma_m =$ **5.300** N/mm^2
Permissible bending stress	$\sigma_{m\_adm} = \sigma_m \times K_3 \times K_7 \times K_8 =$ **8.488** N/mm^2
Applied bending stress	σ_{m_max} = 9 ´ F ´ L_{eff}^2/ (128 ´ Z) = **1.675** N/mm^2

PASS - Applied bending stress within permissible limits

H DESIGNS LTD
10 Almsford Road
Harrogate
North Yorkshire
HG2 8EQ
Tel: 07749 838310
Email: tim@hdesignsltd.co.uk

Scheme	Thorpe Hall, Fylingthorpe	Job Ref. 23/0510
Job	PV Roof Assessment	Sheet no./rev. 10
Calc. by	Timothy Hunt	Date 28/11/2023

Check compressive stress parallel to grain in lower portion of rafter

Compression stress parallel to grain — σ_c = **6.800** N/mm^2

Minimum modulus of elasticity — E_{min} = **5800** N/mm^2

Compression member factor — K_{12} = **0.47**

Permissible compressive stress — $\sigma_{c\_adm} = \sigma_c \times K_3 \times K_8 \times K_{12}$ = **4.400** N/mm^2

Applied compressive stress — σ_{c_max} = 3 ´ F ´ L_{eff} ´ (cot(α) + 13 ´ tan(α) / 3) / (8 ´ A) = **0.328** N/mm^2

PASS - Applied compressive stress within permissible limits

Check combined bending and compressive stress parallel to grain in lower portion of rafter

Euler stress — $\sigma_e = \pi^2 \times E_{min} / \lambda^2$ = **9.231** N/mm^2

Euler coefficient — $K_{eu} = 1 - (1.5 \times \sigma_{c\_max} \times K_{12} / \sigma_e)$ = **0.975**

Combined axial compression and bending check — $\sigma_{m\_max} / (\sigma_{m\_adm} \times K_{eu}) + \sigma_{c\_max} / \sigma_{c\_adm}$ = **0.277 < 1**

PASS - Combined compressive and bending stresses are within permissible limits

Check shear stress

Shear stress parallel to grain — τ = **0.670** N/mm^2

Permissible shear stress — $\tau_{adm} = \tau \times K_3 \times K_8$ = **0.921** N/mm^2

Applied shear stress — τ_{max} = 15 ´ F ´ L_{eff} / (16 ´ A) = **0.164** N/mm^2

PASS - Applied shear stress within permissible limits

Check deflection

Permissible deflection — $\delta_{adm} = 0.003 \times L_{eff}$ = **5.115** mm

Bending deflection — δ_b = F ´ L_{eff}^4 / (185 ´ E_{mean} ´ I) = **1.134** mm

Shear deflection — δ_s = 12 ´ F ´ L_{eff}^2 / (5 ´ E_{mean} ´ A) = **0.081** mm

Total deflection — $\delta_{max} = \delta_b + \delta_s$ = **1.215** mm

PASS - Total deflection within permissible limits

<u>Consider short term load condition</u>

Load duration factor — K_3 = **1.50**

Total UDL perpendicular to rafter — F = F_d ´ cos(α) ´ s + F_j ´ cos(α) = **0.216** kN/m

Notional bearing length — $L_b = [F \times L_{cl} + F_p \times \cos(\alpha)] / [2 \times (b \times \sigma_{cp1} \times K_8 - F)]$ = **5** mm

Effective span — $L_{eff} = L_{cl} + L_b$ = **1707** mm

Check bending stress at purlin

Bending stress parallel to grain — σ_m = **5.300** N/mm^2

Permissible bending stress — $\sigma_{m\_adm} = \sigma_m \times K_3 \times K_7 \times K_8$ = **10.186** N/mm^2

Applied bending stress — σ_{m_max} = F ´ L_{eff}^2/(8 ´ Z)+3 ´ F_p ´ cos(α) ´ L_{eff}/(32 ´ Z) = **4.214** N/mm^2

PASS - Applied bending stress within permissible limits

Check compressive stress parallel to grain at purlin

Compression stress parallel to grain — σ_c = **6.800** N/mm^2

Minimum modulus of elasticity — E_{min} = **5800** N/mm^2

Compression member factor — K_{12} = **0.43**

Permissible compressive stress — $\sigma_{c\_adm} = \sigma_c \times K_3 \times K_8 \times K_{12}$ = **4.779** N/mm^2

Applied compressive stress — σ_{c_max} = 3 ´ F ´ L_{eff} ´ (cot(α)+8 ´ tan(α)/3)/(8 ´ A)+F_p ´ sin(α)/A = **0.309** N/mm^2

PASS - Applied compressive stress within permissible limits

H DESIGNS LTD
10 Almsford Road
Harrogate
North Yorkshire
HG2 8EQ
Tel: 07749 838310
Email: tim@hdesignsltd.co.uk

Scheme	Job Ref.
Thorpe Hall, Fylingthorpe	23/0510
Job	**Sheet no./rev.**
PV Roof Assessment	11
Calc. by	**Date**
Timothy Hunt	28/11/2023

Check combined bending and compressive stress parallel to grain at purlin

Euler stress $\sigma_e = \pi^2 \times E_{min} / \lambda^2 =$ **9.211** N/mm^2

Euler coefficient $K_{eu} = 1 - (1.5 \times \sigma_{c\_max} \times K_{12} / \sigma_e) =$ **0.979**

Combined axial compression and bending check $\sigma_{m\_max} / (\sigma_{m\_adm} \times K_{eu}) + \sigma_{c\_max} / \sigma_{c\_adm} =$ **0.487 < 1**

PASS - Combined compressive and bending stresses are within permissible limits

Check bending stress in lower portion of rafter

Bending stress parallel to grain $\sigma_m =$ **5.300** N/mm^2

Permissible bending stress $\sigma_{m\_adm} = \sigma_m \times K_3 \times K_7 \times K_8 =$ **10.186** N/mm^2

Applied bending stress σ_{m_max} = F ´ L_{eff}^2/(16 ´ Z)+13 ´ F_p ´ cos(α) ´ L_{eff}/(64 ´ Z) = **6.155** N/mm^2

PASS - Applied bending stress within permissible limits

Check compressive stress parallel to grain in lower portion of rafter

Compression stress parallel to grain $\sigma_c =$ **6.800** N/mm^2

Minimum modulus of elasticity $E_{min} =$ **5800** N/mm^2

Compression member factor $K_{12} =$ **0.43**

Permissible compressive stress $\sigma_{c\_adm} = \sigma_c \times K_3 \times K_8 \times K_{12} =$ **4.779** N/mm^2

Applied compressive stress σ_{c_max} = 3 ´ F ´ L_{eff} ´ (cot(α)+4 ´ tan(α))/(8 ´ A)+F_p ´ sin(α)/A = **0.356** N/mm^2

PASS - Applied compressive stress within permissible limits

Check combined bending and compressive stress parallel to grain in lower portion of rafter

Euler stress $\sigma_e = \pi^2 \times E_{min} / \lambda^2 =$ **9.211** N/mm^2

Euler coefficient $K_{eu} = 1 - (1.5 \times \sigma_{c\_max} \times K_{12} / \sigma_e) =$ **0.975**

Combined axial compression and bending check $\sigma_{m\_max} / (\sigma_{m\_adm} \times K_{eu}) + \sigma_{c\_max} / \sigma_{c\_adm} =$ **0.694 < 1**

PASS - Combined compressive and bending stresses are within permissible limits

Check shear stress

Shear stress parallel to grain $\tau =$ **0.670** N/mm^2

Permissible shear stress $\tau_{adm} = \tau \times K_3 \times K_8 =$ **1.106** N/mm^2

Applied shear stress τ_{max} = 15 ´ F ´ L_{eff} / (16 ´ A) + 3 ´ F_p ´ cos(α) / (2 ´ A) = **0.383** N/mm^2

PASS - Applied shear stress within permissible limits

Check deflection

Permissible deflection $\delta_{adm} = 0.003 \times L_{eff} =$ **5.120** mm

Bending deflection δ_b = L_{eff}^3 ´ (F ´ L_{eff} /185 + 0.015 ´ F_p ´ cos(α)) / (E_{mean} ´ I) = **4.112** mm

Shear deflection δ_s = 12 ´ L_{eff} ´ (F ´ L_{eff} +2 ´ F_p ´ cos(α))/(5 ´ E_{mean} ´ A) = **0.225** mm

Total deflection $\delta_{max} = \delta_b + \delta_s =$ **4.337** mm

PASS - Total deflection within permissible limits

SUMMARY

Increase in loading is not sufficient to take the original members out of their designed specification.

Therefore the roof is suitable for the proposed addition of Solar Panels.