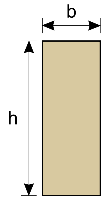
Rafter Design to BS 5268-2 and BS 5268-7.5

Rafter details

Timber strength class	**C24**
Rafter width	b = **50** mm
Rafter depth	h = **225** mm
Rafter spacing	s = **450** mm
Rafter slope	α = **40** degrees
Clear span on slope	$L_{cl,slope}$ = **4.8** m
Brittle finishes (e.g. plasterboard) on the underside of the rafter?	**No**



Diagrams not to scale

Modification factors

Depth factor	$K_7 = (300 / h)^{0.11}$ = **1.03**
Load sharing modification factor (BS5268-2 clause 2.10.11)	K_8 = **1.10**

Section properties

Mean modulus of elasticity	E_{mean} = **10,800** N/mm²
Minimum modulus of elasticity	E_{min} = **7,200** N/mm²
Cross section area	A = b × h = **11,200** mm²
Second moment of area	$I = b \times h^3 / 12$ = **47,500,000** mm⁴
Section modulus	$Z = b \times h^2 / 6$ = **422,000** mm³
Radius of gyration	i = √(I / A) = **65** mm
Average density for C24 timber (BS 5268-2:2002 Table 8)	ρ_{mean} = **420** kg/m³
Self weight per linear metre (g = 9.81 m/s²)	$F_{rafter} = b \times h \times \rho_{mean} \times g$ = **0.0464** kN/m

Consider long term loading (0.75 kN/m² dead UDL. K3 = 1)

K3 (long term load)	K_3 = **1**
Total load	$F = F_{dead} \times \cos(\alpha) \times (s / 1000) + F_{rafter} \times \cos(\alpha)$ = **0.294** kN/m
Grade bending stress for C24 (BS5268-2:2002 Table 8)	$\sigma_{m,par}$ = **7.5** N/mm²
Permissible bending stress	$\sigma_{adm} = \sigma_{m,par} \times K_3 \times K_7 \times K_8$ = **8.52** N/mm²
Compression perpendicular to grain for C24 (BS5268-2:2002 Table 8)	$\sigma_{c,per}$ = **1.9** N/mm²

Notional bearing length
(Note from BS 5268-7.5 Clause 4.2: 'The bearing length required at each end of the rafter, calculated in accordance with 5.6, may not be sufficient for practical construction purposes.')

$a = (L_{cl,slope} \times F / 2) / (\sigma_{c,per} \times K_3 \times K_8 \times b - (F / 2))$ = **6.76** mm

Effective span on slope — $L_{eff} = L_{cl,slope} + a$ = **4.81** m

Check bending stress

Bending moment — $M = F \times L_{eff}^2 / 8$ = **0.849** kNm

Bending stress — $\sigma_{m,a} = (M \times 10^6) / Z$ = **2.01** N/mm²

$\sigma_{m,a} <= \sigma_{adm}$ (2.013 N/mm² <= 8.515 N/mm²) therefore OK

Check shear stress

Grade shear stress for C24 (BS5268-2:2002 Table 8) — τ_{par} = **0.71** N/mm²

Permissible shear stress — $\tau_{adm} = \tau_{par} \times K_3 \times K_8$ = **0.781** N/mm²

Shear stress — $\tau = (3 \times F \times L_{eff} / 2 \times 10^3) / (2 \times b \times h)$ = **0.0942** N/mm²

$\tau <= \tau_{adm}$ (0.094 N/mm² <= 0.781 N/mm²) therefore OK

Check compressive stress parallel to grain

Compression stress parallel to grain — $\sigma_{c,par}$ = **7.9** N/mm²

Minimum modulus of elasticity — E_{min} = **7,200** N/mm²

Slenderness ratio — $\lambda = L_{eff} / i$ = **74**

Compression member factor (calculated using equation in BS5268-7.5 clause 5.3.1) — K_{12} = **0.566**

Permissible compressive stress — $\sigma_{c,adm} = \sigma_{c,par} \times K_3 \times K_8 \times K_{12}$ = **4.92** N/mm²

Applied compressive stress — $\sigma_{c,a}$ = **0.233** N/mm²

$\sigma_{c,a} <= \sigma_{c,adm}$ (0.233 N/mm² <= 4.92 N/mm²) therefore OK

Check combined bending and compressive stress

Euler critical stress — $\sigma_e = \pi^2 \times E_{min} / \lambda^2$ = **13** N/mm²

Euler coefficient — $K_{eu} = 1 - (1.5 \times \sigma_c \times L_{12} / \sigma_e)$ = **0.985**

Combined axial compression and bending check — $= \sigma_{m,a} / (\sigma_{m,adm} \times K_{eu}) + \sigma_c / \sigma_{c,adm}$ = **0.287**

0.287 <= 1 therefore OK

Check deflection

Permissible deflection — $\delta_{adm} = 0.003 \times L_{eff}$ = **14.4** mm

Bending deflection — $\delta_{bending} = (5 \times F \times L_{eff}^4) / (384 \times E_{mean} \times I)$ = **3.99** mm

Shear deflection — $\delta_{shear} = (12 \times F \times L_{eff}^2) / (5 \times E_{mean} \times b \times h)$ = **0.134** mm

Total deflection — $\delta_{total} = \delta_{bending} + \delta_{shear}$ = **4.12** mm

δ_{total} <= δ_{adm} (4.122 mm <= 14.42 mm) therefore OK

Consider medium term loading (0.75 kN/m² dead UDL + 0.75 kN/m² imposed UDL. K3 = 1.25)

K3 (medium term load) — K_3 = **1.25**

BS 5268-7.5 Clause 4.3: For a roof slope greater than 30° and not exceeding 75°: an imposed load obtained by linear interpolation between the values at 30° roof slope, e.g. 0.75 kN/m2, and zero for a 75° roof slope.

Imposed load (UDL)	$F_{imposed,udl} = 0.75 \times ((75 - \alpha) / 45)$ = **0.583** kN/m²
Total load	$F = (F_{imposed,udl} \times \cos(\alpha)^2 + F_{dead} \times \cos(\alpha)) \times (s / 1000) + F_{rafter} \times \cos(\alpha)$ = **0.448** kN/m
Grade bending stress for C24 (BS5268-2:2002 Table 8)	$\sigma_{m,par}$ = **7.5** N/mm²
Permissible bending stress	$\sigma_{adm} = \sigma_{m,par} \times K_3 \times K_7 \times K_8$ = **10.6** N/mm²
Compression perpendicular to grain for C24 (BS5268-2:2002 Table 8)	$\sigma_{c,per}$ = **1.9** N/mm²
Notional bearing length (Note from BS 5268-7.5 Clause 4.2: 'The bearing length required at each end of the rafter, calculated in accordance with 5.6, may not be sufficient for practical construction purposes.')	$a = (L_{cl,slope} \times F / 2) / (\sigma_{c,per} \times K_3 \times K_8 \times b - (F / 2))$ = **8.25** mm
Effective span on slope	$L_{eff} = L_{cl,slope} + a$ = **4.81** m

Check bending stress

Bending moment	$M = F \times L_{eff}^2 / 8$ = **1.29** kNm
Bending stress	$\sigma_{m,a} = (M \times 10^6) / Z$ = **3.07** N/mm²
	$\sigma_{m,a}$ <= σ_{adm} (3.069 N/mm² <= 10.644 N/mm²) therefore OK

Check shear stress

Grade shear stress for C24 (BS5268-2:2002 Table 8)	τ_{par} = **0.71** N/mm²
Permissible shear stress	$\tau_{adm} = \tau_{par} \times K_3 \times K_8$ = **0.976** N/mm²
Shear stress	$\tau = (3 \times F \times L_{eff} / 2 \times 10^3) / (2 \times b \times h)$ = **0.144** N/mm²
	τ <= τ_{adm} (0.144 N/mm² <= 0.976 N/mm²) therefore OK

Check compressive stress parallel to grain

Compression stress parallel to grain	$\sigma_{c,par}$ = **7.9** N/mm²
Minimum modulus of elasticity	E_{min} = **7,200** N/mm²
Slenderness ratio	$\lambda = L_{eff} / i$ = **74**
Compression member factor (calculated using equation in BS5268-7.5 clause 5.3.1)	K_{12} = **0.522**
Permissible compressive stress	$\sigma_{c,adm} = \sigma_{c,par} \times K_3 \times K_8 \times K_{12}$ = **5.67** N/mm²
Applied compressive stress	$\sigma_{c,a}$ = **0.355** N/mm²

$\sigma_{c,a} <= \sigma_{c,adm}$ (0.355 N/mm² <= 5.668 N/mm²) therefore OK

Check combined bending and compressive stress

Euler critical stress — $\sigma_e = \pi^2 \times E_{min} / \lambda^2 =$ **13** N/mm²

Euler coefficient — $K_{eu} = 1 - (1.5 \times \sigma_c \times L_{12} / \sigma_e) =$ **0.979**

Combined axial compression and bending check — $= \sigma_{m,a} / (\sigma_{m,adm} \times K_{eu}) + \sigma_c / \sigma_{c,adm} =$ **0.357**

0.357 <= 1 therefore OK

Check deflection

Permissible deflection — $\delta_{adm} = 0.003 \times L_{eff} =$ **14.4** mm

Bending deflection — $\delta_{bending} = (5 \times F \times L_{eff}^4) / (384 \times E_{mean} \times I) =$ **6.08** mm

Shear deflection — $\delta_{shear} = (12 \times F \times L_{eff}^2) / (5 \times E_{mean} \times b \times h) =$ **0.205** mm

Total deflection — $\delta_{total} = \delta_{bending} + \delta_{shear} =$ **6.29** mm

$\delta_{total} <= \delta_{adm}$ (6.289 mm <= 14.425 mm) therefore OK

Design summary

	Permissible	Applied/Actual	Utilisation	Result
Long term load shear stress (N/mm²)	0.78	0.09	12.1 %	OK
Long term load bending stress (N/mm²)	8.52	2.01	23.6 %	OK
Long term load deflection (mm)	14.4	4.12	28.6 %	OK
Long term compressive stress parallel to grain (N/mm²)	4.92	0.23	4.7 %	OK
Long term combined bending and compressive stress (N/mm²)	1	0.29	28.7 %	OK
Medium term load shear stress (N/mm²)	0.98	0.14	14.7 %	OK
Medium term load bending stress (N/mm²)	10.6	3.07	28.8 %	OK
Medium term load deflection (mm)	14.4	6.29	43.6 %	OK
Medium term compressive stress parallel to grain (N/mm²)	5.67	0.36	6.3 %	OK
Medium term combined bending and compressive stress (N/mm²)	1	0.36	35.7 %	OK

Notes

This design is in accordance with BS 5268-2:2002 Structural use of timber - Part 2: Code of practice for permissible stress design, materials and workmanship and BS 5268-7.5:1990 Structural use of timber - Section 7.5 Domestic rafters.

These calculations apply to systems of at least four rafters, and having tiling battens adequate to provide lateral distribution and lateral support.

Timber to be covered, this calculation is not to be used for timber which is fully exposed to the elements.

As there are no brittle finishes e.g. plasterboard on the underside of the rafters the effects of deflection under the concentrated (point) load do not need to be considered as per guidance given in BS 5268-7.5 clause 4.3.

For roof slopes greater than 30 degrees, the concentrated (point) 0.9 kN load can be ignored in accordance with BS 5268-7.5 Clause 4.3.

These calculations are only applicable for roofs consisting of four or more rafters.

Wane as allowed in BS 4978:2007 + A2:2017 is permitted.