# Flitch Beam Design (BS 5268-2:2002 & BS 449)

## Beam details

| | |
|---|---|
| Timber strength class | **C24** |
| Service class of timber | **2** |
| Timber width | $b_t$ = **47** mm |
| Timber depth | $h_t$ = **195** mm |
| Steel grade | Grade **43** |
| Steel width | $b_s$ = **10** mm |
| Steel depth | $h_s$ = **180** mm |
| Bolt diameter | **12** mm |
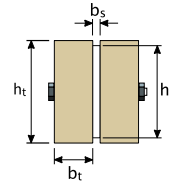
## Span details

| | |
|---|---|
| Beam clear span | $L_{cl}$ = **3.7** m |
| Bearing length | $L_b$ = **100** mm |
| Beam effective span | $L_{eff}$ = $L_{cl}$ + (2 × ($L_b$ / 2)) = **3.8** m |
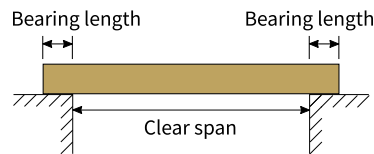
Diagrams not to scale

## Loading details
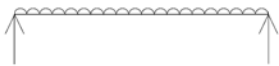
**Load 1: UDL - Sloping roof, 0° to 30°**

| Dead load | $F_{d,1}$ = **1.15** kN/m² × **1** m = **1.15** kN/m |
|---|---|
| Imposed load | $F_{i,1}$ = **0.75** kN/m² × **1** m = **0.75** kN/m |

**Load 2: UDL - Flat roof, with no permanent access**

| Dead load | $F_{d,2}$ = **1** kN/m² × **1.5** m = **1.5** kN/m |
|---|---|
| Imposed load | $F_{i,2}$ = **0.75** kN/m² × **1.5** m = **1.125** kN/m |

## Reactions (unfactored)

| | Dead | Imposed | Total |
|---|---|---|---|
| Left reaction | **5.44** kN | **3.56** kN | **9.00** kN |
| Right reaction | **5.44** kN | **3.56** kN | **9.00** kN |

## Modification factors

Timber service class modification factor K2 as table 16

| | |
|---|---|
| Bending parallel to grain | $K_{2,ben}$ = **1.00** |
| Compression perpendicular to grain | $K_{2,per}$ = **1.00** |
| Shear parallel to grain | $K_{2,shr}$ = **1.00** |
| Mean & min modulus of elasticity | $K_{2,mod}$ = **1.00** |
| Load duration factor | $K_3$ = **1.25** |

From BS5268-2 Table 18, bearing is < 75mm from joist end.

| | |
|---|---|
| Bearing modification factor | $K_4$ = **1.00** |
| Depth factor | $K_7 = (300 / h)^{0.11}$ = **1.05** |
| Load sharing modification factor (BS5268-2 clause 2.10.11) | $K_8$ = **1.10** |
| Modulus of elasticity modification factor (BS5268-2 clause 2.9) | $K_9$ = **1.14** |

## Modular ratio of steel to timber

| | |
|---|---|
| Timber minimum modulus of elasticity | $E_{min}$ = **7,200** N/mm² |
| Modulus of elasticity for grade 43 steel | $E_{st}$ = **205,000** N/mm² |
| The minimum modulus of elasticity modified by the factor K9 should be used for deflections | $E = E_{min} \times K_{2,mod} \times K_9$ = **8,210** N/mm² |
| Modular ratio | $MR = E_{st} / E$ = **25** |

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| | Calcs for<br>Mr Andy Grundy 19a Grimshaw Lane Bollington SK10 5PT | Date<br>13 Oct 2023 |

## Section properties

| | |
|---|---|
| Equivalent timber Area of section | $EA$ = No. steel pieces × $MR$ × $b_s$ × $d_s$ + No. timber pieces × ($b_t$ × $d_t$) = **63,300** mm² |
| Inertia of timber about xx axis | $I_t$ = No. timber members × $b_t$ × $d_t^3$ / 12 = **58,100,000** mm⁴ |
| Modified Inertia of steel about xx axis | $I_s$ = No. steel plates × $MR$ × $b_s$ × $d_s^3$ / 12 = **121,000,000** mm⁴ |
| Total Inertia about xx axis in equivalent timber | $I_{xx}$ = $I_t$ + $I_s$ = **179,000,000** mm⁴ |
| Distance to edge of steel | $Y_s$ = $d_s$ / 2 = **90** mm |
| Distance to edge of timber | $Y_t$ = $d_t$ / 2 = **97.5** mm |
| Extreme fibre is timber section | $Y_c$ = $Y_t$ = **97.5** mm |
| Dist of centroid to steel edge | $Y_n$ = $Y_s$ = **90** mm |
| Z to top edge of timber | $Z_c$ = $I_{xx}$ / $Y_c$ = **1,840,000** mm³ |
| Average density for C24 grade timber (BS 5268-2:2002 Table 8) | $\rho_{mean}$ = **420** kg/m³ |
| Self weight of timber (g = 9.81 m/s²) | $F_{self, timber}$ = ($b_t$ × $h_t$ × $\rho_{mean}$) × $L_{eff}$ × g = **287** N |
| Self weight of steel (g = 9.81 m/s²) | $F_{self, steel}$ = ($b_s$ × $h_s$ × $\rho_{steel}$) × $L_{eff}$ × g = **527** N |
| Total self weight (g = 9.81 m/s²) | $F_{self}$ = **814** N |

## Section design parameters

| | |
|---|---|
| Design bending moment | $M_b$ = **8,550,000** Nmm |
| Design shear force | $F_{ve}$ = **9,000** N |

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## Check bending stress



Bending moments (kNm)
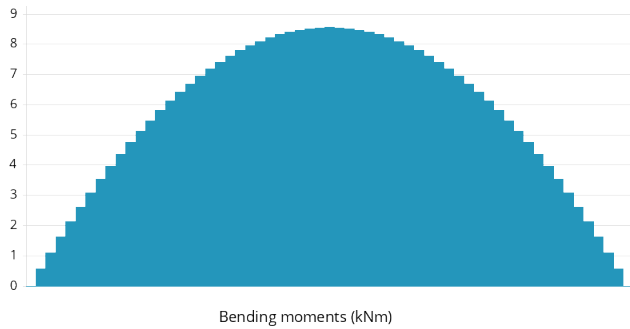
Strains in the timber and steel are the same at the same distance from the neutral axis. Since $Y_t > Y_s$ ( 97.5 mm > 90 mm ) the modified steel stress will be less than that of the timber as a ratio of the distances $Y_s$ and $Y_t$.

| | |
| --- | --- |
| Timber grade bending stress parallel to grain (BS5268-2 Table 8) | $\sigma_{t,m,g,par}$ = **7.5** N/mm² |
| Permissible timber bending stress (factored) | $\sigma_{t,m,adm} = \sigma_{t,m,g,par} \times K_{2,ben} \times K_3 \times K_7 \times K_8$ = **10.8** N/mm² |
| Maximum bending moment | M = **8.55** kNm |
| Applied bending stress in timber | $\sigma_{t,m,max} = M/Z_c$ = **4.65** N/mm² |

> **Pass**   $\sigma_{t,m,max} <= \sigma_{t,m,adm}$ ( 4.647 N/mm² <= 10.813 N/mm² ) applied bending stress in timber within permissible

| | |
| --- | --- |
| Permissible steel stress from table 2 BS449, grade 43 steel, with a fully restrained section assumed in design, steel plate less than or equal to 40 mm thick | $\sigma_{s,adm}$ = **180** N/mm² |
| Applied bending stress in steel | $\sigma_{s,m,max} = \sigma_{t,m,max} \times MR \times Y_n / Y_c$ = **107** N/mm² |

> **Pass**   $\sigma_{s,m,max} <= \sigma_{s,adm}$ ( 107.141 N/mm² <= 180 N/mm² ) applied bending stress in steel within permissible

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## Check deflection (including shear deflection as required by clause 2.10.7)
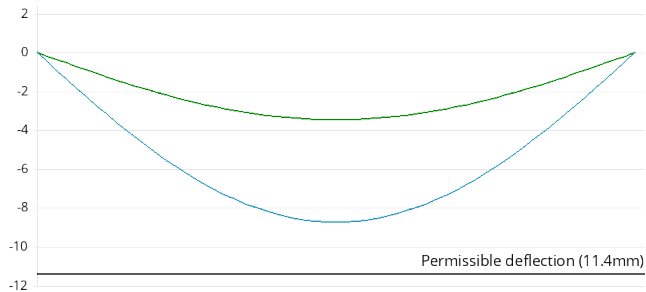


Live load deflection (green) and total load deflection (blue) in mm

Deflection based on E = 8208 N/mm²

| | |
|---|---|
| Dead load deflection without shear | $\delta_d$ = **5.28** mm |
| Imposed load deflection without shear | $\delta_l$ = **3.46** mm |
| Total dead & imposed load deflection | $\delta_t$ = **8.73** mm |
| Modulus of rigidity | G = E / 16 = **513** N/mm² |
| Shape factor for rectangular section | $K_F$ = **1.2** |
| Shear area for beam | $A_y$ = EA / $K_F$ = **52,700** mm² |
| Total dead and imposed load | W = **18** kN |
| If total dead & imposed load applied as a UDL, additional deflection due to shear | $\delta_{su}$ = W × $L_{eff}$ × $10^6$/(8 × $A_y$ × G) = **0.316** mm |
| Shear deflection | $\delta_{shear}$ = $\delta_{su}$ × $M_b$/(W × L/8) = **0.316** mm |
| Permissible deflection | $\delta_{adm}$ = 0.003 × L × $10^3$ = **11.4** mm |
| Total deflection inclusive of shear | $\delta_{max}$ = $\delta_d$ + $\delta_l$ + $\delta_{shear}$ = **9.05** mm |

**Pass**   $\delta_{max}$ <= $\delta_{adm}$ ( 9.05 mm <= 11.4 mm ), therefore OK for deflection

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## Check shear stress



No notches to occur at the critical shear position.

Timber grade shear stress parallel to grain (BS5268-2 Table 8)

$\tau_{t,g,par}$ = **0.71** N/mm²

Permissible shear parallel to grain (factored)

$\tau_{t,adm} = \tau_{t,g,par} \times K_{2,shr} \times K_3 \times K_8$ = **0.976** N/mm²

Permissible shear force on timber

$F_{t,adm} = 2 \times \tau_{t,adm} \times$ No. timber members $\times b_t \times d_t / 3$ = **11,900** N

Design shear force

$F_{ve}$ = **9,000** N

**Pass** $F_{ve} <= F_{t,adm}$ ( 9004.33 N <= 11929.775 N ) applied shear force is less than the shear capacity of timber alone, therefore **OK**

## Check bearing stress

Timber grade compressive stress perpendicular to grain (BS5268-2 Table 8)

$\sigma_{t,c,g,⊥}$ = **1.9** N/mm²

Permissible compressive stress perpendicular to grain (factored)

$\sigma_{t,c,adm} = \sigma_{t,c,g,⊥} \times K_{2,per} \times K_3 \times K_4 \times K_8$ = **2.61** N/mm²

Timber bearing stress on support

$\sigma_{t,c,max} = F_{ve}/(L_b \times$ No. timber members $\times b_t)$ = **0.958** N/mm²

**Pass** $\sigma_{t,c,max} <= \sigma_{t,c,adm}$ ( 0.958 N/mm² <= 2.613 N/mm² ) bearing stress is less than permissible timber stress, therefore OK

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## Bolts between timber and steel plates along beam

Total load on beam $\qquad$ W = total left reaction + total right reaction = **18** kN

Maximum reaction at bearing $\qquad$ $R_{max}$ = **9** kN

Basic bolt shear capacity (tables 69-73) $\qquad$ $V_{capacity}$ = **2.23** kN

Number of interfaces $\qquad$ $N_{interfaces}$ = **2**

Minimum number of bolts required at bearings calc $\qquad$ $N_{bolts, bearings, calc}$ = $R_{max}$ / ($N_{interfaces}$ × $V_{capacity}$) = **2.02**

Limiting bolt spacing $\qquad$ $S_{limit}$ = min(2.5 × $h_t$, 600) = **488** mm

Minimum number of bolts along length of beam $\qquad$ $N_{bolts\_along\_length}$ = W / ($N_{interfaces}$ × $V_{capacity}$) = **4.04**

Bolts to be staggered along the length of the beam, alternately set $h_t$/4 **= 48.8 mm** above and below the centre line.

Bolts are to be spaced at **487.5 mm maximum** centres.

Bolts at the supports are to be located 0.5 x the bearing length ($L_b$) **= 50 mm** from the inner edge of the support.

Minimum end and edge distances in the timber are to be 4 x bolt diameter = **48 mm**.

## Design summary

| | Permissible | Applied/Actual | Utilisation | Result |
|---|---|---|---|---|
| Shear force (kN) | 11.9 | 9 | 75.5 % | **OK** |
| Timber bending stress (N/mm²) | 10.8 | 4.65 | 43 % | **OK** |
| Steel bending stress (N/mm²) | 180 | 107 | 59.5 % | **OK** |
| Bearing stress (N/mm²) | 2.61 | 0.96 | 36.7 % | **OK** |
| Deflection (mm) | 11.4 | 9.05 | 79.4 % | **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 BS449 - Specification for the use of structural steel in building.

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

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