

EC5 Timber Fastener Capacity Check

EN 1995-1-1:2004

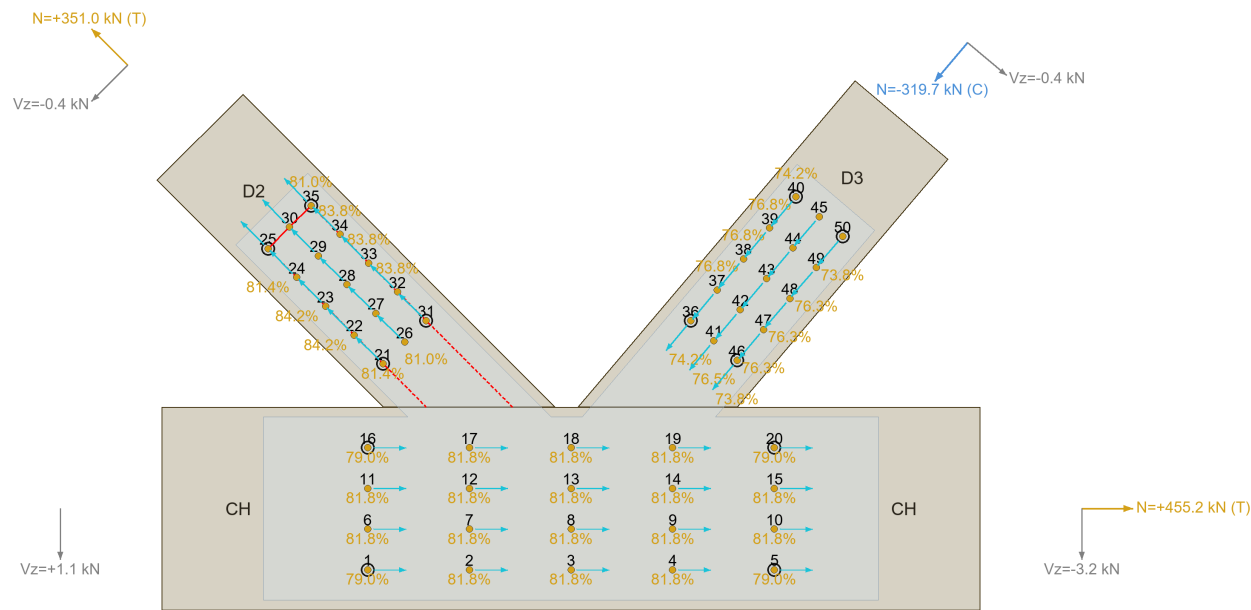
Date: 2026-08-11
Load Case: manual

Input Data Summary

Timber class	GL24h
Service class	1
Load duration	Medium-term
Fastener type	Dowel
Fastener diameter	12 mm
Fastener grade	S235 (235/360)
Dowel-to-bolt swaps	12 dowels exported as bolts (class 4.6); reason: corner presets; EC5 checks remain dowel checks
Plate thickness	10.0 mm
Plate grade	S355
Plate type	Inserted
Number of plates	2
Outer plate $\pm y$	46.7 mm
Slot tolerance	1.0 mm (per side)
Recess	20.0 mm/end
a3 end-distance offset	0.0 mm

Connection Views

SIDE VIEW (XZ)



• eta ≤ 70% • 70% < eta ≤ 90% • 90% < eta ≤ 100% • eta > 100% FAIL

Members

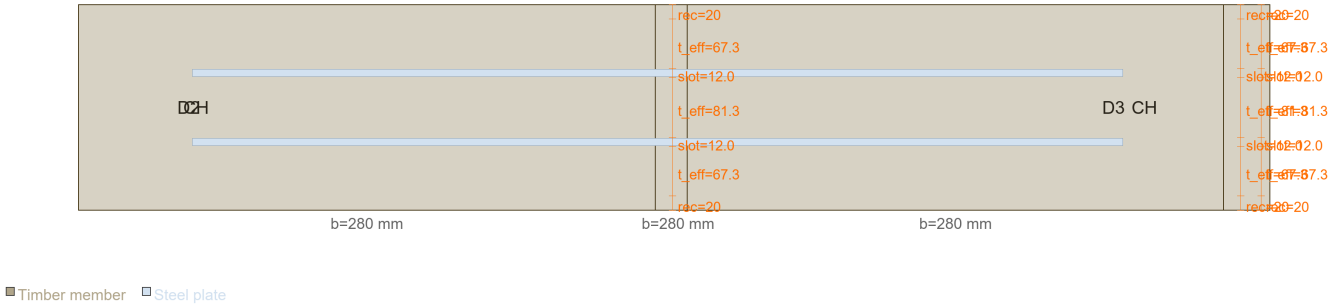
Name	Bearing	b [mm]	h [mm]	Cross-section
CH	Yes	280	400	280 x 400
D2	No	280	240	280 x 240
D3	No	280	240	280 x 240

Member Loads (LC: manual)

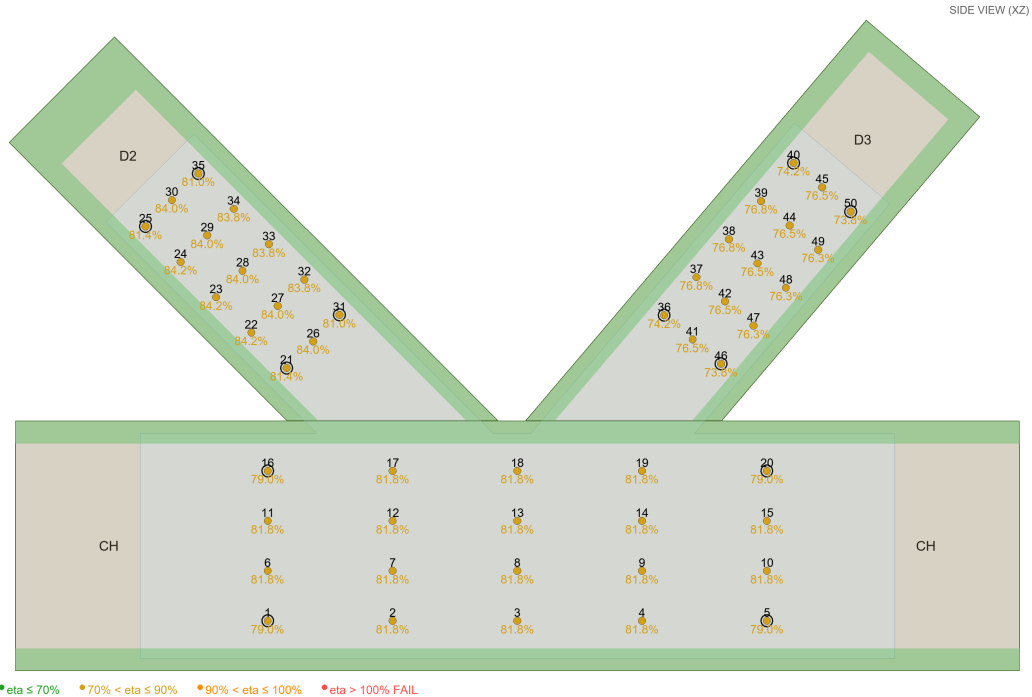
Member	N [kN]	T/C	Vz [kN]	Vy [kN]	My [kNm]	Mz [kNm]	T [kNm]
CH / Begin	0.00	C	1.09	0.00	0.00	0.00	0.00
CH / End	455.24	T	-3.17	0.00	0.00	0.00	0.00
D2 / End	350.98	T	-0.36	0.00	0.00	0.00	0.00
D3 / End	-319.69	C	-0.41	0.00	0.00	0.00	0.00

Equilibrium (Forces through node): X -0.08 Y +0.00 Z -0.06 kN Mx +0.00 My +0.00 Mz +0.00 kNm (balanced)
+ Lever arm (fastener group centroid x Vz): My +0.02 kNm
Equilibrium (Forces through fastener centroid): X -0.08 Y +0.00 Z -0.06 kN Mx +0.00 My +0.02 Mz +0.00 kNm (balanced)

TOP VIEW (XY)



Spacing Validation - S8.5.1.1(3)



a3 end-distance + a4 edge-distance zones, shown exactly as the on-screen side view (green = pass, red = fail).

Member CH

a1 PARALLEL SPACING $a_{1,min} = (3 + 2 \cos \alpha) \cdot d = 60.0 \text{ mm}$ actual = 200.0 mm ✓ PASS
a2 PERPENDICULAR SPACING $a_{2,min} = 36.0 \text{ mm}$ actual = 80.0 mm ✓ PASS
a4,t EDGE DISTANCE (loaded) $a_{4,t,min} = \max((2+2 \sin \alpha)d, 3d) = 36.0 \text{ mm}$ actual = 80.0 mm ✓ PASS
a4,c EDGE DISTANCE (unloaded) $a_{4,c,min} = 3d = 36.0 \text{ mm}$ actual = 80.0 mm ✓ PASS

Member D2

a1 PARALLEL SPACING $a_{1,min} = (3 + 2 \cos \alpha) \cdot d = 60.0 \text{ mm}$ actual = 80.0 mm ✓ PASS
a2 PERPENDICULAR SPACING $a_{2,min} = 36.0 \text{ mm}$ actual = 60.0 mm ✓ PASS
a3,t END DISTANCE (loaded) $a_{3,t,min} = \max(7d, 80) = 84.0 \text{ mm}$ actual = 120.0 mm ✓ PASS
a4,t EDGE DISTANCE (loaded) $a_{4,t,min} = \max((2+2 \sin \alpha)d, 3d) = 36.0 \text{ mm}$ actual = 60.0 mm ✓ PASS
a4,c EDGE DISTANCE (unloaded) $a_{4,c,min} = 3d = 36.0 \text{ mm}$ actual = 60.0 mm ✓ PASS

Member D3

a1 PARALLEL SPACING $a_{1,min} = (3 + 2 \cos \alpha) \cdot d = 60.0 \text{ mm}$ actual = 80.0 mm ✓ PASS
a2 PERPENDICULAR SPACING $a_{2,min} = 36.0 \text{ mm}$ actual = 60.0 mm ✓ PASS
a3,c END DISTANCE (unloaded) $a_{3,c,min} = 36.0 \text{ mm}$ actual = 120.0 mm ✓ PASS

a_{4,t} EDGE DISTANCE (loaded)

$a_{4,t,min} = \max((2+2|\sin \alpha|)d, 3d) = \mathbf{36.0\ mm}$ actual = **60.0 mm** ✓ **PASS**

a_{4,c} EDGE DISTANCE (unloaded)

$a_{4,c,min} = 3d = \mathbf{36.0\ mm}$ actual = **60.0 mm** ✓ **PASS**

Fastener Capacity - EN 1995-1-1:2004

Failure-mode compatibility (S8.1.3(2)): COMPATIBLE. All 50 multi-shear fastener(s) have every shear plane in the yielding family, so the per-plane Johansen capacities ARE summed (Sigma basis).

Fastener	a[°]	t [mm]	f _{ha}	V _{Ed,Σ}	F _{vRd,Σ}	ηΣ%	V _{Ed,pl}	F _{vRd,pl}	ηpl%	Compat	LC	Status	Md
B1	1	67/10/81/10/67	27.8	22.77	28.80	79.0	7.59	6.96	109.1	Yes	man...	PASS	g m m g
D2	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
D3	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
D4	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
B5	1	67/10/81/10/67	27.8	22.77	28.80	79.0	7.59	6.96	109.1	Yes	man...	PASS	g m m g
D6	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
D7	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
D8	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
D9	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
D10	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
D11	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
D12	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
D13	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
D14	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
D15	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
B16	1	67/10/81/10/67	27.8	22.77	28.80	79.0	7.59	6.96	109.1	Yes	man...	PASS	g m m g
D17	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
D18	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
D19	1	67/10/81/10/67	27.8	22.77	27.84	81.8	7.59	6.86	110.7	Yes	man...	PASS	g m m g
B20	1	67/10/81/10/67	27.8	22.77	28.80	79.0	7.59	6.96	109.1	Yes	man...	PASS	g m m g
B21	0	67/10/81/10/67	27.8	23.46	28.81	81.4	7.82	6.96	112.4	Yes	man...	PASS	g m m g
D22	0	67/10/81/10/67	27.8	23.46	27.84	84.2	7.82	6.86	114.0	Yes	man...	PASS	g m m g
D23	0	67/10/81/10/67	27.8	23.46	27.84	84.2	7.82	6.86	114.0	Yes	man...	PASS	g m m g
D24	0	67/10/81/10/67	27.8	23.46	27.84	84.2	7.82	6.86	114.0	Yes	man...	PASS	g m m g
B25	0	67/10/81/10/67	27.8	23.46	28.81	81.4	7.82	6.96	112.4	Yes	man...	PASS	g m m g
D26	0	67/10/81/10/67	27.8	23.40	27.84	84.0	7.80	6.86	113.7	Yes	man...	PASS	g m m g
D27	0	67/10/81/10/67	27.8	23.40	27.84	84.0	7.80	6.86	113.7	Yes	man...	PASS	g m m g
D28	0	67/10/81/10/67	27.8	23.40	27.84	84.0	7.80	6.86	113.7	Yes	man...	PASS	g m m g
D29	0	67/10/81/10/67	27.8	23.40	27.84	84.0	7.80	6.86	113.7	Yes	man...	PASS	g m m g
D30	0	67/10/81/10/67	27.8	23.40	27.84	84.0	7.80	6.86	113.7	Yes	man...	PASS	g m m g
B31	0	67/10/81/10/67	27.8	23.34	28.81	81.0	7.78	6.96	111.8	Yes	man...	PASS	g m m g
D32	0	67/10/81/10/67	27.8	23.34	27.84	83.8	7.78	6.86	113.4	Yes	man...	PASS	g m m g
D33	0	67/10/81/10/67	27.8	23.34	27.84	83.8	7.78	6.86	113.4	Yes	man...	PASS	g m m g
D34	0	67/10/81/10/67	27.8	23.34	27.84	83.8	7.78	6.86	113.4	Yes	man...	PASS	g m m g
B35	0	67/10/81/10/67	27.8	23.34	28.81	81.0	7.78	6.96	111.8	Yes	man...	PASS	g m m g
B36	1	67/10/81/10/67	27.8	21.38	28.80	74.2	7.13	6.96	102.4	Yes	man...	PASS	g m m g
D37	0	67/10/81/10/67	27.8	21.38	27.84	76.8	7.13	6.86	103.9	Yes	man...	PASS	g m m g
D38	0	67/10/81/10/67	27.8	21.38	27.84	76.8	7.13	6.86	103.9	Yes	man...	PASS	g m m g
D39	0	67/10/81/10/67	27.8	21.38	27.84	76.8	7.13	6.86	103.9	Yes	man...	PASS	g m m g
B40	0	67/10/81/10/67	27.8	21.38	28.81	74.2	7.13	6.96	102.4	Yes	man...	PASS	g m m g
D41	1	67/10/81/10/67	27.8	21.31	27.84	76.5	7.10	6.86	103.6	Yes	man...	PASS	g m m g
D42	0	67/10/81/10/67	27.8	21.31	27.84	76.5	7.10	6.86	103.6	Yes	man...	PASS	g m m g
D43	0	67/10/81/10/67	27.8	21.31	27.84	76.5	7.10	6.86	103.6	Yes	man...	PASS	g m m g
D44	0	67/10/81/10/67	27.8	21.31	27.84	76.5	7.10	6.86	103.6	Yes	man...	PASS	g m m g
D45	0	67/10/81/10/67	27.8	21.31	27.84	76.5	7.10	6.86	103.6	Yes	man...	PASS	g m m g
B46	1	67/10/81/10/67	27.8	21.25	28.80	73.8	7.08	6.96	101.8	Yes	man...	PASS	g m m g
D47	0	67/10/81/10/67	27.8	21.25	27.84	76.3	7.08	6.86	103.3	Yes	man...	PASS	g m m g
D48	0	67/10/81/10/67	27.8	21.25	27.84	76.3	7.08	6.86	103.3	Yes	man...	PASS	g m m g
D49	0	67/10/81/10/67	27.8	21.25	27.84	76.3	7.08	6.86	103.3	Yes	man...	PASS	g m m g
B50	0	67/10/81/10/67	27.8	21.25	28.81	73.8	7.08	6.96	101.8	Yes	man...	PASS	g m m g

Gray values are supplementary and never set the row verdict.

Compatible-mode fasteners: $\eta = V_{Ed,Sigma} / F_{v,Rd,Sigma}$

Mode-incompatible fasteners: $\eta = V_{Ed,gov} / F_{v,Rd,gov}$ per S8.1.3(2)

Per-plane capacities cannot be summed across embedment + yielding mode families.

Fastener Johansen Derivation - EN 1995-1-1:2004

Critical fastener D22 (member D2)

EN 1995-1-1:2004 · Dowel · governs LC manual

EMBEDMENT STRENGTH, PARALLEL TO GRAIN - EC5 (8.32)

$$f_{h,0,k} = 0.082 \cdot (1 - 0.01 \cdot d) \cdot \rho_k = 0.082 \cdot (1 - 0.01 \cdot 12.0) \cdot 385 = \mathbf{27.78 \text{ MPa}}$$

SOFTWOOD CORRECTION FACTOR - EC5 (8.33)

$$k_{90} = 1.35 + 0.015 \cdot d = 1.35 + 0.015 \cdot 12.0 = \mathbf{1.530}$$

EMBEDMENT STRENGTH AT ANGLE α - EC5 (8.31)

$$f_{h,\alpha,k} = \frac{f_{h,0,k}}{k_{90} \cdot \sin^2 \alpha + \cos^2 \alpha} = 27.78 / (1.530 \cdot 0.0000 + 1.0000) = \mathbf{27.78 \text{ MPa}}$$

CHARACTERISTIC YIELD MOMENT - EC5 (8.30)

$$M_{y,Rk} = 0.3 \cdot f_{u,k} \cdot d^{2.6} = 0.3 \cdot 360 \cdot 12.0^{2.6} = \mathbf{69071 \text{ N}\cdot\text{mm}}$$

JOHANSEN MODE (f) - EC5 (8.11)

$$F_{v,Rk} = f_{h,1,k} \cdot t_1 \cdot d = 27.78 \cdot 67.3 \cdot 12.0 = \mathbf{22.45 \text{ kN}}$$



JOHANSEN MODE (g) - EC5 (8.11) ← GOVERNS

$$F_{v,Rk} = f_{h,1,k} \cdot t_1 \cdot d \cdot [\sqrt{(2 + 4M_{y,Rk} / (f_{h,1,k} \cdot d \cdot t_1^2))} - 1] = 22446 \cdot 0.4774 = \mathbf{10.72 \text{ kN}}$$



JOHANSEN MODE (h) - EC5 (8.11)

$$F_{v,Rk} = 2.30 \cdot \sqrt{M_{y,Rk} \cdot f_{h,1,k} \cdot d} = 2.30 \cdot \sqrt{69071 \cdot 27.78 \cdot 12.0} = \mathbf{11.04 \text{ kN}}$$



INNER-PLANE MODE (l) - EC5 (8.13)

$$F_{v,Rk} = 0.5 \cdot f_{h,\alpha,k} \cdot t_{\text{inner}} \cdot d = 0.5 \cdot 27.78 \cdot 81.3 \cdot 12.0 = \mathbf{13.56 \text{ kN}}$$



INNER-PLANE MODE (m) - EC5 (8.13) ← GOVERNS

$$F_{v,Rk} = 2.3 \cdot \sqrt{M_{y,Rk} \cdot f_{h,\alpha,k} \cdot d} = 2.3 \cdot \sqrt{69071 \cdot 27.78 \cdot 12.0} = \mathbf{11.04 \text{ kN}}$$



PER-PLANE CAPACITY (4 shear planes, §8.1.3(1)) - EC5 (8.1.3)

Plane outer-1 (outer, t=67.3 mm): $F_{v,Rk} = 10.72 \text{ kN}$ [mode g]

Plane inner-L (inner, t=81.3 mm): $F_{v,Rk} = 11.04 \text{ kN}$ [mode m]

Plane inner-R (inner, t=81.3 mm): $F_{v,Rk} = 11.04 \text{ kN}$ [mode m]

Plane outer-2 (outer, t=67.3 mm): $F_{v,Rk} = 10.72 \text{ kN}$ [mode g]

$F_{v,Rk,\text{total}} = \Sigma \text{ planes} = \mathbf{43.51 \text{ kN}}$

MODE COMPATIBILITY (§8.1.3(2)) - EC5 (8.1.3)

per-plane modes: **g|m|m|g**

one family -> COMPATIBLE: per-plane capacities summed

DESIGN CAPACITY - EC5 §2.4.1 (2.17)

$$F_{v,Rd} = \frac{k_{\text{mod}} \cdot F_{v,Rk}}{\gamma_M} = (0.80 \cdot 43.51) / 1.25 = \mathbf{27.84 \text{ kN}}$$

UTILISATION - EC5 (2.17)

$$\eta = \frac{V_{\text{Ed}}}{F_{v,Rd}} = 23.46 / 27.84 = \mathbf{0.84 \leq 1.0 \quad \checkmark \text{ PASS}}$$

Effective Fastener Count (n_ef) - S8.5.1.1(4)

Member CH

N_EF FAMILY ROUTING Family routing: dowel -> 8.5.1 (EN 8.6(1))
EFFECTIVE FASTENER COUNT - per row ($\alpha = 0.5^\circ$) - EC5 (8.34/8.35) Row 1 (n=5): $\min(5, 5^{0.9.4\sqrt{(200/(13\cdot12))}})$, interp $\alpha \rightarrow n_{ef} = 4.53$ Row 2 (n=5): $\min(5, 5^{0.9.4\sqrt{(200/(13\cdot12))}})$, interp $\alpha \rightarrow n_{ef} = 4.53$ Row 3 (n=5): $\min(5, 5^{0.9.4\sqrt{(200/(13\cdot12))}})$, interp $\alpha \rightarrow n_{ef} = 4.53$ Row 4 (n=5): $\min(5, 5^{0.9.4\sqrt{(200/(13\cdot12))}})$, interp $\alpha \rightarrow n_{ef} = 4.53$ $\Sigma n_{ef} = 4.53 + 4.53 + 4.53 + 4.53 = 18.12$ effective fasteners
MIXED DOWEL + FITTED-BOLT GROUP - EC5 (8.1.1) 16 dowel(s) + 4 fitted bolt(s); weaker = dowel, governing mode g Step 2 pro-rate: $n_{ef,d} = 14.50$, $n_{ef,b} = 3.62$ Step 3 DUCTILE: $F_{group} = 14.50 \times 27.84 + 3.62 \times 28.80 = 508.0$ kN Fitted bolts assumed unthreaded (full shank); $d_{ef} = d$.
GROUP UTILISATION (EC5, mixed) - EC5 (8.1.1)/(2.17) $\eta = F_{Ed} / F_{v,Rd,group} = 455.24 / 508.0 = 0.90 \leq 1.0 \quad \checkmark$ PASS

Member D2

N_EF FAMILY ROUTING Family routing: dowel -> 8.5.1 (EN 8.6(1))
EFFECTIVE FASTENER COUNT - per row ($\alpha = 0.1^\circ$) - EC5 (8.34/8.35) Row 1 (n=5): $\min(5, 5^{0.9.4\sqrt{(80/(13\cdot12))}})$, interp $\alpha \rightarrow n_{ef} = 3.60$ Row 2 (n=5): $\min(5, 5^{0.9.4\sqrt{(80/(13\cdot12))}})$, interp $\alpha \rightarrow n_{ef} = 3.60$ Row 3 (n=5): $\min(5, 5^{0.9.4\sqrt{(80/(13\cdot12))}})$, interp $\alpha \rightarrow n_{ef} = 3.60$ $\Sigma n_{ef} = 3.60 + 3.60 + 3.60 = 10.80$ effective fasteners
MIXED DOWEL + FITTED-BOLT GROUP - EC5 (8.1.1) 11 dowel(s) + 4 fitted bolt(s); weaker = dowel, governing mode g Step 2 pro-rate: $n_{ef,d} = 7.92$, $n_{ef,b} = 2.88$ Step 3 DUCTILE: $F_{group} = 7.92 \times 27.84 + 2.88 \times 28.81 = 303.5$ kN Fitted bolts assumed unthreaded (full shank); $d_{ef} = d$.
GROUP UTILISATION (EC5, mixed) - EC5 (8.1.1)/(2.17) $\eta = F_{Ed} / F_{v,Rd,group} = 350.98 / 303.5 = 1.16 > 1.0 \quad \times$ FAIL

Member D3

N_EF FAMILY ROUTING Family routing: dowel -> 8.5.1 (EN 8.6(1))
EFFECTIVE FASTENER COUNT - per row ($\alpha = 0.1^\circ$) - EC5 (8.34/8.35) Row 1 (n=5): $\min(5, 5^{0.9.4\sqrt{(80/(13\cdot12))}})$, interp $\alpha \rightarrow n_{ef} = 3.60$ Row 2 (n=5): $\min(5, 5^{0.9.4\sqrt{(80/(13\cdot12))}})$, interp $\alpha \rightarrow n_{ef} = 3.60$ Row 3 (n=5): $\min(5, 5^{0.9.4\sqrt{(80/(13\cdot12))}})$, interp $\alpha \rightarrow n_{ef} = 3.60$ $\Sigma n_{ef} = 3.60 + 3.60 + 3.60 = 10.80$ effective fasteners
MIXED DOWEL + FITTED-BOLT GROUP - EC5 (8.1.1) 11 dowel(s) + 4 fitted bolt(s); weaker = dowel, governing mode g Step 2 pro-rate: $n_{ef,d} = 7.92$, $n_{ef,b} = 2.88$ Step 3 DUCTILE: $F_{group} = 7.92 \times 27.84 + 2.88 \times 28.80 = 303.5$ kN Fitted bolts assumed unthreaded (full shank); $d_{ef} = d$.
GROUP UTILISATION (EC5, mixed) - EC5 (8.1.1)/(2.17) $\eta = F_{Ed} / F_{v,Rd,group} = 319.69 / 303.5 = 1.05 > 1.0 \quad \times$ FAIL

Block Shear (D2) - EC5 Annex A

Settings: plug shear = ON block-shear sum = ON

NET FRACTURE LENGTHS + MATERIAL - EC5 Annex A $L_{net,v} = \sum l_{v,i} = \mathbf{892.0\text{ mm}}$ $L_{net,t} = \text{gross} - \sum \text{holes} = \mathbf{96.0\text{ mm}}$ $f_{t,0,k} = 19.2\text{ MPa} \quad f_{v,k} = 3.5\text{ MPa} \quad k_{cr} = 0.67 \quad k_{mod} = 0.80 \quad \gamma_M = 1.25$
SEGMENT 0 (outer, t_seg = 67.3 mm) ← GOVERNS - EC5 Annex A $A_{net,v} = \frac{1}{2} \cdot L_{net,v} \cdot (L_{net,t} + 2 \cdot t_{ef}) \cdot k_{cr} = \frac{1}{2} \cdot 892.0 \cdot (96.0 + 2 \cdot 29.1) \cdot 0.67 = \mathbf{46072\text{ mm}^2}$ $A_{net,t} = L_{net,t} \cdot t_{seg} = 96.0 \cdot 67.3 = \mathbf{6464\text{ mm}^2}$ $F_{bs,Rk} = \max(1.5 \cdot A_{net,t} \cdot f_{t,0,k}, 0.7 \cdot A_{net,v} \cdot f_{v,k}) = \max(186.2, 112.9) = \mathbf{186.15\text{ kN (tension)}}$ $F_{bs,Rd} = k_{mod} \cdot F_{bs,Rk} / \gamma_M = 0.80 \cdot 186.15 / 1.25 = \mathbf{119.14\text{ kN}}$ $\eta_{seg} = \text{demand} / F_{bs,Rd} = 109.41 / 119.14 = \mathbf{0.92 \leq 1.0 \checkmark PASS}$
SEGMENT 1 (inner, t_seg = 81.3 mm) - EC5 Annex A $A_{net,v} = k_{cr} \cdot L_{net,v} \cdot t_{seg} = 0.67 \cdot 892.0 \cdot 81.3 = \mathbf{48612\text{ mm}^2}$ $A_{net,t} = L_{net,t} \cdot t_{seg} = 96.0 \cdot 81.3 = \mathbf{7809\text{ mm}^2}$ $F_{bs,Rk} = \max(1.5 \cdot A_{net,t} \cdot f_{t,0,k}, 0.7 \cdot A_{net,v} \cdot f_{v,k}) = \max(224.9, 119.1) = \mathbf{224.89\text{ kN (tension)}}$ $F_{bs,Rd} = k_{mod} \cdot F_{bs,Rk} / \gamma_M = 0.80 \cdot 224.89 / 1.25 = \mathbf{143.93\text{ kN}}$ $\eta_{seg} = \text{demand} / F_{bs,Rd} = 132.17 / 143.93 = \mathbf{0.92 \leq 1.0 \checkmark PASS}$
SEGMENT 2 (outer, t_seg = 67.3 mm) - EC5 Annex A $A_{net,v} = \frac{1}{2} \cdot L_{net,v} \cdot (L_{net,t} + 2 \cdot t_{ef}) \cdot k_{cr} = \frac{1}{2} \cdot 892.0 \cdot (96.0 + 2 \cdot 29.1) \cdot 0.67 = \mathbf{46072\text{ mm}^2}$ $A_{net,t} = L_{net,t} \cdot t_{seg} = 96.0 \cdot 67.3 = \mathbf{6464\text{ mm}^2}$ $F_{bs,Rk} = \max(1.5 \cdot A_{net,t} \cdot f_{t,0,k}, 0.7 \cdot A_{net,v} \cdot f_{v,k}) = \max(186.2, 112.9) = \mathbf{186.15\text{ kN (tension)}}$ $F_{bs,Rd} = k_{mod} \cdot F_{bs,Rk} / \gamma_M = 0.80 \cdot 186.15 / 1.25 = \mathbf{119.14\text{ kN}}$ $\eta_{seg} = \text{demand} / F_{bs,Rd} = 109.41 / 119.14 = \mathbf{0.92 \leq 1.0 \checkmark PASS}$
BLOCK SHEAR SUM (plastic redistribution, GOVERNS) - EC5 Annex A $\Sigma F_{bs,Rk} = 186.15 + 224.89 + 186.15 = \mathbf{597.20\text{ kN}}$ $\Sigma F_{bs,Rd} = k_{mod} \cdot \Sigma F_{bs,Rk} / \gamma_M = 0.80 \cdot 597.20 / 1.25 = \mathbf{382.21\text{ kN}}$ $\eta = N_{Ed} / \Sigma F_{bs,Rd} = 350.98 / 382.21 = \mathbf{0.92 \leq 1.0 \checkmark PASS}$

Members not requiring a block-shear check:

- CH: N/A - continuous
- D3: N/A - compression

Perpendicular Splitting - S8.1.4

Member CH

CHARACTERISTIC SPLITTING CAPACITY - EC5 (8.4)

$$F_{90,Rk} = 14 \cdot b \cdot w \cdot \sqrt{h_e / (1 - h_e/h)} = 14 \cdot 280 \cdot 1.0 \cdot \sqrt{320 / (1 - 320/400)} = \mathbf{156.80 \text{ kN}}$$

DESIGN SPLITTING CAPACITY - EC5 (2.4.3)

$$F_{90,Rd} = k_{mod} \cdot F_{90,Rk} / \gamma_M = 0.80 \cdot 156.80 / 1.25 = \mathbf{100.35 \text{ kN}}$$

SPLITTING UTILISATION - EC5 (8.1.4)

$$\eta = F_{v,Ed} / F_{90,Rd} = 3.17 / 100.35 = \mathbf{0.03 \leq 1.0 \quad \checkmark \text{ PASS}}$$

Member D2

CHARACTERISTIC SPLITTING CAPACITY - EC5 (8.4)

$$F_{90,Rk} = 14 \cdot b \cdot w \cdot \sqrt{h_e / (1 - h_e/h)} = 14 \cdot 280 \cdot 1.0 \cdot \sqrt{180 / (1 - 180/240)} = \mathbf{105.19 \text{ kN}}$$

DESIGN SPLITTING CAPACITY - EC5 (2.4.3)

$$F_{90,Rd} = k_{mod} \cdot F_{90,Rk} / \gamma_M = 0.80 \cdot 105.19 / 1.25 = \mathbf{67.32 \text{ kN}}$$

SPLITTING UTILISATION - EC5 (8.1.4)

$$\eta = F_{v,Ed} / F_{90,Rd} = 0.36 / 67.32 = \mathbf{0.01 \leq 1.0 \quad \checkmark \text{ PASS}}$$

Member D3

CHARACTERISTIC SPLITTING CAPACITY - EC5 (8.4)

$$F_{90,Rk} = 14 \cdot b \cdot w \cdot \sqrt{h_e / (1 - h_e/h)} = 14 \cdot 280 \cdot 1.0 \cdot \sqrt{180 / (1 - 180/240)} = \mathbf{105.19 \text{ kN}}$$

DESIGN SPLITTING CAPACITY - EC5 (2.4.3)

$$F_{90,Rd} = k_{mod} \cdot F_{90,Rk} / \gamma_M = 0.80 \cdot 105.19 / 1.25 = \mathbf{67.32 \text{ kN}}$$

SPLITTING UTILISATION - EC5 (8.1.4)

$$\eta = F_{v,Ed} / F_{90,Rd} = 0.41 / 67.32 = \mathbf{0.01 \leq 1.0 \quad \checkmark \text{ PASS}}$$

Member Net Cross-Section - S5.2 / S6.1

Member CH

NET WIDTH + HOLE DIAMETER - EC5 5.2

$$b_{\text{net}} = W - n_{\text{pl}} \cdot (t_{\text{steel}} + 2 \cdot \text{slot}) = 280.0 - 2 \cdot (10.0 + 2 \cdot 1.0) = \mathbf{256.0 \text{ mm}} \quad (\text{steel-plate slot removed})$$
$$d_0 = d + \text{oversize} = 12 + 0 = \mathbf{12 \text{ mm}} \quad (\text{drilled timber hole})$$

NET CROSS-SECTION AREA - EC5 5.2

$$A_{\text{net}} = A_{\text{gross}} - n \cdot d_0 \cdot b = 102400 - 4 \cdot 12 \cdot 256 = \mathbf{90112 \text{ mm}^2}$$

DESIGN TENSILE STRENGTH (parallel) - EC5 6.1.2

$$f_{t,0,d} = k_{\text{mod}} \cdot k_h \cdot f_{t,0,k} / \gamma_M = 0.80 \cdot 1.0414 \cdot 19.2 / 1.25 = \mathbf{12.796 \text{ MPa}}$$

NET-SECTION TENSILE UTILISATION - EC5 6.1.2

$$\eta = \sigma_{t,0,d} / f_{t,0,d} = 5.052 / 12.796 = \mathbf{0.39 \leq 1.0 \quad \checkmark \text{ PASS}}$$

BENDING STRESS AT NET SECTION - EC5 6.1.6

$$\sigma_m = M_y \cdot z_s / I_{\text{net}} = 0.000\text{e}+00 \cdot 200 / 1.267\text{e}+09 = \mathbf{0.000 \text{ MPa}} \quad (f_{m,d} = 15.996 \text{ MPa})$$

TENSION + BENDING INTERACTION - EC5 6.2.3

$$\eta = \sigma_{t,0,d} / f_{t,0,d} + \sigma_m / f_{m,d} = 0.395 + 0.000 = \mathbf{0.39 \leq 1.0 \quad \checkmark \text{ PASS}}$$

NET-SECTION SHEAR UTILISATION - EC5 6.1.7

$$\tau_v = V_z \cdot S_{\text{net}} / (I_{\text{net}} \cdot b \cdot k_{cr}) = 3170 \cdot 4.63\text{e}+06 / (1.27\text{e}+09 \cdot 256 \cdot 0.67) = \mathbf{0.068 \text{ MPa}}$$
$$\eta = \tau_v / f_{v,d} = 0.068 / 2.240 = \mathbf{0.03 \leq 1.0 \quad \checkmark \text{ PASS}}$$

MOMENT-INDUCED SHEAR UTILISATION - EC5 6.1.7

$$V_{dw} = 0.0 \text{ kN} \quad (= V_M)$$
$$\tau_{dw} = V_{dw} \cdot S_{\text{net}} / (I_{\text{net}} \cdot b \cdot k_{cr}) = 0 \cdot 4.63\text{e}+06 / (1.27\text{e}+09 \cdot 256 \cdot 0.67) = \mathbf{0.000 \text{ MPa}}$$
$$\eta = \tau_{dw} / f_{v,d} = 0.000 / 2.240 = \mathbf{0.00 \leq 1.0 \quad \checkmark \text{ PASS}}$$

GOVERNING NET-SECTION UTILISATION

$$\eta_{\text{gov}} = \max(\text{axial}, N+M, \text{current shear}) = \mathbf{0.39 \leq 1.0 \quad \checkmark \text{ PASS}}$$

Member D2

NET WIDTH + HOLE DIAMETER - EC5 5.2

$$b_{\text{net}} = W - n_{\text{pl}} \cdot (t_{\text{steel}} + 2 \cdot \text{slot}) = 280.0 - 2 \cdot (10.0 + 2 \cdot 1.0) = \mathbf{256.0 \text{ mm}} \quad (\text{steel-plate slot removed})$$
$$d_0 = d + \text{oversize} = 12 + 0 = \mathbf{12 \text{ mm}} \quad (\text{drilled timber hole})$$

NET CROSS-SECTION AREA - EC5 5.2

$$A_{\text{net}} = A_{\text{gross}} - n \cdot d_0 \cdot b = 61440 - 3 \cdot 12 \cdot 256 = \mathbf{52224 \text{ mm}^2}$$

DESIGN TENSILE STRENGTH (parallel) - EC5 6.1.2

$$f_{t,0,d} = k_{\text{mod}} \cdot k_h \cdot f_{t,0,k} / \gamma_M = 0.80 \cdot 1.0792 \cdot 19.2 / 1.25 = \mathbf{13.261 \text{ MPa}}$$

NET-SECTION TENSILE UTILISATION - EC5 6.1.2

$$\eta = \sigma_{t,0,d} / f_{t,0,d} = 6.721 / 13.261 = \mathbf{0.51 \leq 1.0 \quad \checkmark \text{ PASS}}$$

BENDING STRESS AT NET SECTION - EC5 6.1.6

$$\sigma_m = M_y \cdot z_s / I_{\text{net}} = 0.000\text{e}+00 \cdot 120 / 2.727\text{e}+08 = \mathbf{0.000 \text{ MPa}} \quad (f_{m,d} = 16.834 \text{ MPa})$$

TENSION + BENDING INTERACTION - EC5 6.2.3

$$\eta = \sigma_{t,0,d} / f_{t,0,d} + \sigma_m / f_{m,d} = 0.507 + 0.000 = \mathbf{0.51 \leq 1.0 \quad \checkmark \text{ PASS}}$$

NET-SECTION SHEAR UTILISATION - EC5 6.1.7

$$\tau_v = V_z \cdot S_{\text{net}} / (I_{\text{net}} \cdot b \cdot k_{cr}) = 360 \cdot 1.66\text{e}+06 / (2.73\text{e}+08 \cdot 256 \cdot 0.67) = \mathbf{0.013 \text{ MPa}}$$
$$\eta = \tau_v / f_{v,d} = 0.013 / 2.240 = \mathbf{0.01 \leq 1.0 \quad \checkmark \text{ PASS}}$$

MOMENT-INDUCED SHEAR UTILISATION - EC5 6.1.7

$$V_{dw} = 0.0 \text{ kN} \quad (= V_M)$$

$$\tau_{dw} = V_{dw} \cdot S_{net} / (I_{net} \cdot b \cdot k_{cr}) = 0 \cdot 1.66e+06 / (2.73e+08 \cdot 256 \cdot 0.67) = \mathbf{0.000 \text{ MPa}}$$

$$\eta = \tau_{dw} / f_{v,d} = 0.000 / 2.240 = \mathbf{0.00 \leq 1.0 \quad \checkmark \text{ PASS}}$$

GOVERNING NET-SECTION UTILISATION

$$\eta_{gov} = \max(\text{axial, N+M, current shear}) = \mathbf{0.51 \leq 1.0 \quad \checkmark \text{ PASS}}$$

Member D3**NET WIDTH + HOLE DIAMETER - EC5 5.2**

$$b_{net} = W - n_{pl} \cdot (t_{steel} + 2 \cdot \text{slot}) = 280.0 - 2 \cdot (10.0 + 2 \cdot 1.0) = \mathbf{256.0 \text{ mm}} \quad (\text{steel-plate slot removed})$$

$$d_0 = d + \text{oversize} = 12 + 0 = \mathbf{12 \text{ mm}} \quad (\text{drilled timber hole})$$

NET CROSS-SECTION AREA - EC5 5.2

$$A_{net} = A_{gross} - n \cdot d_0 \cdot b = 61440 - 3 \cdot 12 \cdot 256 = \mathbf{52224 \text{ mm}^2}$$

DESIGN COMPRESSIVE STRENGTH (parallel) - EC5 6.1.4

$$f_{c,0,d} = k_{mod} \cdot f_{c,0,k} / \gamma_M = 0.80 \cdot 24.0 / 1.25 = \mathbf{15.360 \text{ MPa}}$$

NET-SECTION COMPRESSIVE UTILISATION - EC5 6.1.4

$$\eta = \sigma_{c,0,d} / f_{c,0,d} = 6.122 / 15.360 = \mathbf{0.40 \leq 1.0 \quad \checkmark \text{ PASS}}$$

BENDING STRESS AT NET SECTION - EC5 6.1.6

$$\sigma_m = M_y \cdot z_s / I_{net} = 0.000e+00 \cdot 120 / 2.727e+08 = \mathbf{0.000 \text{ MPa}} \quad (f_{m,d} = 16.834 \text{ MPa})$$

COMPRESSION + BENDING INTERACTION - EC5 6.2.4

$$\eta = (\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_m / f_{m,d} = 0.159 + -0.000 = \mathbf{0.16 \leq 1.0 \quad \checkmark \text{ PASS}}$$

NET-SECTION SHEAR UTILISATION - EC5 6.1.7

$$\tau_v = V_z \cdot S_{net} / (I_{net} \cdot b \cdot k_{cr}) = 410 \cdot 1.66e+06 / (2.73e+08 \cdot 256 \cdot 0.67) = \mathbf{0.015 \text{ MPa}}$$

$$\eta = \tau_v / f_{v,d} = 0.015 / 2.240 = \mathbf{0.01 \leq 1.0 \quad \checkmark \text{ PASS}}$$

MOMENT-INDUCED SHEAR UTILISATION - EC5 6.1.7

$$V_{dw} = 0.0 \text{ kN} \quad (= V_M)$$

$$\tau_{dw} = V_{dw} \cdot S_{net} / (I_{net} \cdot b \cdot k_{cr}) = 0 \cdot 1.66e+06 / (2.73e+08 \cdot 256 \cdot 0.67) = \mathbf{0.000 \text{ MPa}}$$

$$\eta = \tau_{dw} / f_{v,d} = 0.000 / 2.240 = \mathbf{0.00 \leq 1.0 \quad \checkmark \text{ PASS}}$$

GOVERNING NET-SECTION UTILISATION

$$\eta_{gov} = \max(\text{axial, N+M, current shear}) = \mathbf{0.40 \leq 1.0 \quad \checkmark \text{ PASS}}$$

Fastener Capacity

EN 1993-1-8:2005 + AC:2009 (Steel plate gate)

Independent of EC5/FprEN Johansen

F4 conservative path (steel/bolt check)

MIN end/edge distances, resultant fastener magnitude

Fastener	Class	V_Ed,pl[kN]	F_b,Rd[kN]	etaB%	V_Ed,pn[kN]	F_v,Rd[kN]	etaV%	Gov	Status
B1	end/edg	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D2	inn/edg	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D3	inn/edg	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D4	inn/edg	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
B5	end/edg	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D6	end/inn	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D7	inn/inn	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D8	inn/inn	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D9	inn/inn	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D10	end/inn	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D11	end/inn	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D12	inn/inn	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D13	inn/inn	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D14	inn/inn	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D15	end/inn	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
B16	end/edg	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D17	inn/edg	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D18	inn/edg	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
D19	inn/edg	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
B20	end/edg	11.38	86.40	13.2	7.59	14.57	52.1	shear	PASS
B21	end/edg	11.73	86.40	13.6	7.82	14.57	53.7	shear	PASS
D22	inn/edg	11.73	86.40	13.6	7.82	14.57	53.7	shear	PASS
D23	inn/edg	11.73	86.40	13.6	7.82	14.57	53.7	shear	PASS
D24	inn/edg	11.73	86.40	13.6	7.82	14.57	53.7	shear	PASS
B25	end/edg	11.73	86.40	13.6	7.82	14.57	53.7	shear	PASS
D26	end/inn	11.70	86.40	13.5	7.80	14.57	53.5	shear	PASS
D27	inn/inn	11.70	86.40	13.5	7.80	14.57	53.5	shear	PASS
D28	inn/inn	11.70	86.40	13.5	7.80	14.57	53.5	shear	PASS
D29	inn/inn	11.70	86.40	13.5	7.80	14.57	53.5	shear	PASS
D30	end/inn	11.70	86.40	13.5	7.80	14.57	53.5	shear	PASS
B31	end/edg	11.67	86.40	13.5	7.78	14.57	53.4	shear	PASS
D32	inn/edg	11.67	86.40	13.5	7.78	14.57	53.4	shear	PASS
D33	inn/edg	11.67	86.40	13.5	7.78	14.57	53.4	shear	PASS
D34	inn/edg	11.67	86.40	13.5	7.78	14.57	53.4	shear	PASS
B35	end/edg	11.67	86.40	13.5	7.78	14.57	53.4	shear	PASS
B36	end/edg	10.69	86.40	12.4	7.13	14.57	48.9	shear	PASS
D37	inn/edg	10.69	86.40	12.4	7.13	14.57	48.9	shear	PASS
D38	inn/edg	10.69	86.40	12.4	7.13	14.57	48.9	shear	PASS
D39	inn/edg	10.69	86.40	12.4	7.13	14.57	48.9	shear	PASS
B40	end/edg	10.69	86.40	12.4	7.13	14.57	48.9	shear	PASS
D41	end/inn	10.66	86.40	12.3	7.10	14.57	48.8	shear	PASS
D42	inn/inn	10.66	86.40	12.3	7.10	14.57	48.8	shear	PASS
D43	inn/inn	10.66	86.40	12.3	7.10	14.57	48.8	shear	PASS
D44	inn/inn	10.66	86.40	12.3	7.10	14.57	48.8	shear	PASS
D45	end/inn	10.66	86.40	12.3	7.10	14.57	48.8	shear	PASS
B46	end/edg	10.62	86.40	12.3	7.08	14.57	48.6	shear	PASS
D47	inn/edg	10.62	86.40	12.3	7.08	14.57	48.6	shear	PASS
D48	inn/edg	10.62	86.40	12.3	7.08	14.57	48.6	shear	PASS
D49	inn/edg	10.62	86.40	12.3	7.08	14.57	48.6	shear	PASS
B50	end/edg	10.62	86.40	12.3	7.08	14.57	48.6	shear	PASS

Plate S355, t = 10.0 mm, gamma_M2 = 1.25, threads in shear. 50 fasteners checked, 0 EC3-FAIL.

Only the Status cell is coloured by verdict (green PASS / red FAIL); all other values are neutral.

Per-plate demand sums two adjoining face forces (multi-plate Q5).

EC3 is an INDEPENDENT verification - both timber Johansen and this steel gate must pass independently.

Steel Plate Net Cross-Section (EN 1993-1-1 6.2.3 / 6.2.4)

Net rupture / gross yield of the plate(s) carrying each member axial force

Member	Type	N_Ed[kN]	A_net[mm ²]	N_Rd[kN]	eta%	Status
CH	tension	455.2	6960	2555.7	17.8	PASS
D2	tension	351.0	4020	1476.1	23.8	PASS
D3	compression	-319.7	4020	1704.0	18.8	PASS

Tension: min(gross yield $A \cdot f_y / \gamma_{M0}$, net rupture $0.9 \cdot A_{net} \cdot f_u / \gamma_{M2}$); compression uses the gross area.

- 6.2.4: compression -> gross area (fastener holes filled by bolts)

- plate depth capped at the member depth (shared-gusset guard)

Verdict

Member	Check	eta [%]	Status
CH	Critical fastener (D2)	81.8	PASS
D2	Critical fastener (D22)	84.2	PASS
D3	Critical fastener (D37)	76.8	PASS
CH	Group capacity (n_ef, mixed fasteners)	89.6	PASS
D2	Group capacity (n_ef, mixed fasteners)	115.7	FAIL
D3	Group capacity (n_ef, mixed fasteners)	105.3	FAIL
D2	Block / plug shear	91.8	PASS
CH	Perpendicular splitting	3.2	PASS
D2	Perpendicular splitting	0.5	PASS
D3	Perpendicular splitting	0.6	PASS
CH	Net cross-section	39.5	PASS
D2	Net cross-section	50.7	PASS
D3	Net cross-section	39.9	PASS

Failure-mode compatibility (S8.1.3(2)): COMPATIBLE

FINAL VERDICT: FAIL

Governing utilisation: eta = 115.7% (D2 Group capacity (n_ef, mixed fasteners))