

Architectural PANEL SOLUTIONS Downer® System Calculations	PROJECT	The Boatmans				JOB REF. SC23-02-015	
	LOCATION	Manchester M15 4QF				DATE: 21/02/2023	
		Input by IS	Date 21/02/2023	Checked	Date	Approved	Date

PROJECT INFORMATION

Cladding	Other	
Thickness	10	mm
System	Face Fix	
Galv steel top hat	None	(0mm)
Substrate	Fixing design by others - through holes	
Notes	Design to loading advised below	
Rail Type	60 Stem x 40 face x 2 L angle	
Bracket Type	All 88mm high	
Thermostop pad	Thermostop	
Cavity Width	108	mm
L Rail horizontal spacing	600	mm
Top hat span		mm
Rail height	1.520	m
No. of spans of rail	3	

APPLIED LOADINGS

A) Vertical Loads	
Self-weight of panel =	19.4 kg/m ²
Support system =	3.6 kg/m ²
TOTAL =	23.04 kg/m ²
B) Horizontal Loads	
Calculated wind =	1.17 kN/m ²
Check reverse load case	Yes

DEFLECTION REQUIREMENTS

Cont. span/defl ratio =	L/200
Cantilever defl. Ratio =	L/150
Max total deflection =	2 mm

SPAN DEFINITIONS (FROM BASE)

Span No.		
1	300.0 mm	Cantilever
2	920.0 mm	Supported each end
3	300.0 mm	Cantilever
Total height =	1.520 m	

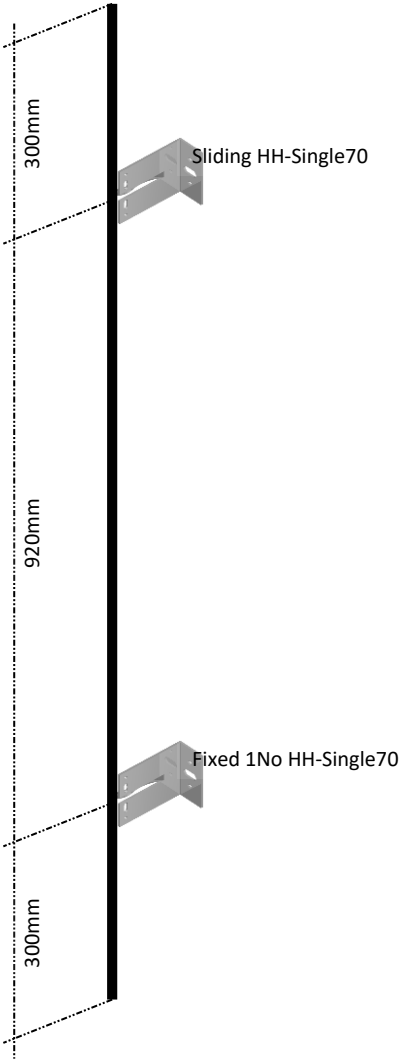
Dead fix bracket pos'n	Top of	Span 1
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RESULTS

Sheeting Rail	Type	60 Stem x 40 face x 2 L angle	PASS	98%
	Max deflection	0.61 mm		
Dead load bracket	Type	HH-Single70	PASS	20%
	Number per rail	1		
	Fixings	2No Client to specify	Design to loading advised below	
	Peak load in fixing to structure:	Pullout = 0.67 kN ULS	Shear =	0.14 kN ULS
Wind restraint bracket	Type	HH-Single70	PASS	9%
	Number per rail	1		
	Fixings	2No Client to specify	Design to loading advised below	
	Peak load in fixing to structure:	Pullout = 0.40 kN ULS		
NOTES	Maximum cavity for selected components		114 mm	
	Minimum cavity for selected components		89 mm	
	Current cavity zone		108 mm	
	(Includes allowance for 0mm of panel fixings, 5mm thermal pad and 0mm top hat)			

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INDICATIVE ARRANGEMENT

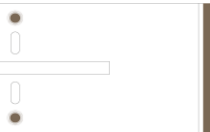


Rail length: 1520mm
Vertical rail: 60 Stem x 40 face x 2 L angle
Set @ max: 600mm cts

Note
Arrangement drawing is indicative only.
All dimensions shown represent the centreline position of the bracket (or bracket group if multiple dead load brackets are required).

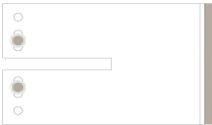
DCS031 Bracket Arrangement:

Fix Point (dead load)



Rail to bracket fixing:
2 No JT4 4 4.8x19

Sliding Point (wind restraint & rail expansion)



Rail to bracket fixing:
2 No JT4 4 4.8x19

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Thickness	10	mm
System	Face Fix	
Galv steel top hat	None	(0mm)
Substrate	Fixing design by others - through holes	
Notes	Design to loading advised below	
Rail Type	60 Stem x 40 face x 2 L angle	
Bracket Type	All 88mm high	
Thermostop pad	Thermostop	
Cavity Width	108	mm
L Rail horizontal spacing	600	mm
Top hat span		mm
Rail height	2.240	m
No. of spans of rail	4	

APPLIED LOADINGS

A) Vertical Loads	
Self-weight of panel =	19.4 kg/m ²
Support system =	3.4 kg/m ²
TOTAL =	22.79 kg/m ²
B) Horizontal Loads	
Calculated wind =	1.17 kN/m ²
Check reverse load case	Yes

DEFLECTION REQUIREMENTS

Cont. span/defl ratio =	L/200
Cantilever defl. Ratio =	L/150
Max total deflection =	2 mm

SPAN DEFINITIONS (FROM BASE)

Span No.

1	300.0 mm	Cantilever
2	820.0 mm	Supported each end
3	820.0 mm	Supported each end
4	300.0 mm	Cantilever

Total height = 2.240 m

Dead fix bracket pos'n	Top of	Span 1
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RESULTS

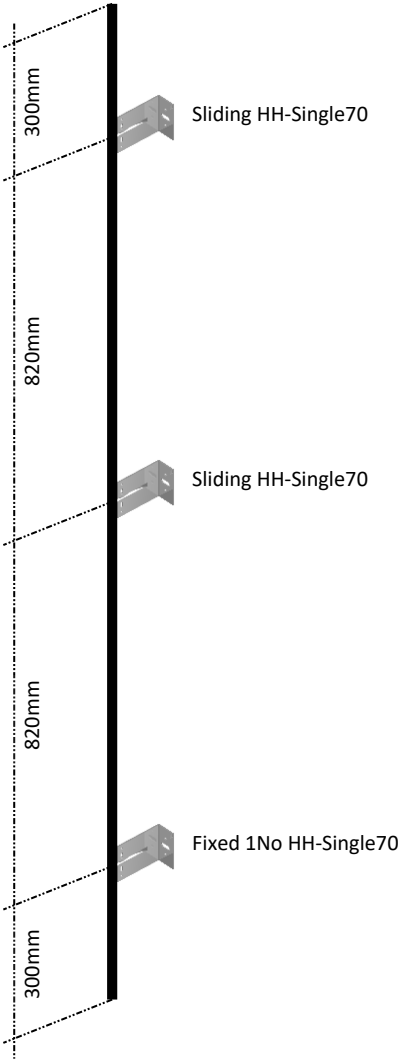
Sheeting Rail	Type	60 Stem x 40 face x 2 L angle	PASS	99%
	Max deflection	0.19 mm		
Dead load bracket	Type	HH-Single70	PASS	30%
	Number per rail	1		
	Fixings	2No Client to specify	Design to loading advised below	
	Peak load in fixing to structure:	Pullout = 0.75 kN ULS	Shear = 0.20 kN ULS	
Wind restraint bracket	Type	HH-Single70	PASS	11%
	Number per rail	2		
	Fixings	2No Client to specify	Design to loading advised below	
	Peak load in fixing to structure:	Pullout = 0.45 kN ULS		

NOTES

Maximum cavity for selected components	114 mm
Minimum cavity for selected components	89 mm
Current cavity zone	108 mm
(Includes allowance for 0mm of panel fixings, 5mm thermal pad and 0mm top hat)	

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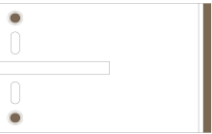


Rail length: 2240mm
Vertical rail: 60 Stem x 40 face x 2 L angle
Set @ max: 600mm cts

Note
Arrangement drawing is indicative only.
All dimensions shown represent the centreline position of the bracket (or bracket group if multiple dead load brackets are required).

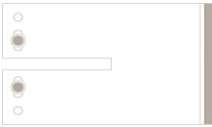
DCS031 Bracket Arrangement:

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Rail to bracket fixing:
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Thickness	10	mm
System	Face Fix	
Galv steel top hat	None	(0mm)
Substrate	Fixing design by others - through holes	
Notes	Design to loading advised below	
Rail Type	60 Stem x 40 face x 2 L angle	
Bracket Type	All 88mm high	
Thermostop pad	Thermostop	
Cavity Width	108	mm
L Rail horizontal spacing	600	mm
Top hat span		mm
Rail height	3.120	m
No. of spans of rail	5	

APPLIED LOADINGS

A) Vertical Loads	
Self-weight of panel =	19.4 kg/m ²
Support system =	3.2 kg/m ²
TOTAL =	22.64 kg/m ²

B) Horizontal Loads	
Calculated wind =	1.17 kN/m ²
Check reverse load case	Yes

DEFLECTION REQUIREMENTS

Cont. span/defl ratio =	L/200
Cantilever defl. Ratio =	L/150
Max total deflection =	2 mm

SPAN DEFINITIONS (FROM BASE)

Span No.		
1	300.0 mm	Cantilever
2	840.0 mm	Supported each end
3	840.0 mm	Supported each end
4	840.0 mm	Supported each end
5	300.0 mm	Cantilever

Total height = 3.120 m

Dead fix bracket pos'n	Top of	Span 1
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RESULTS

Sheeting Rail	Type	60 Stem x 40 face x 2 L angle	PASS	99%
	Max deflection	0.24 mm		

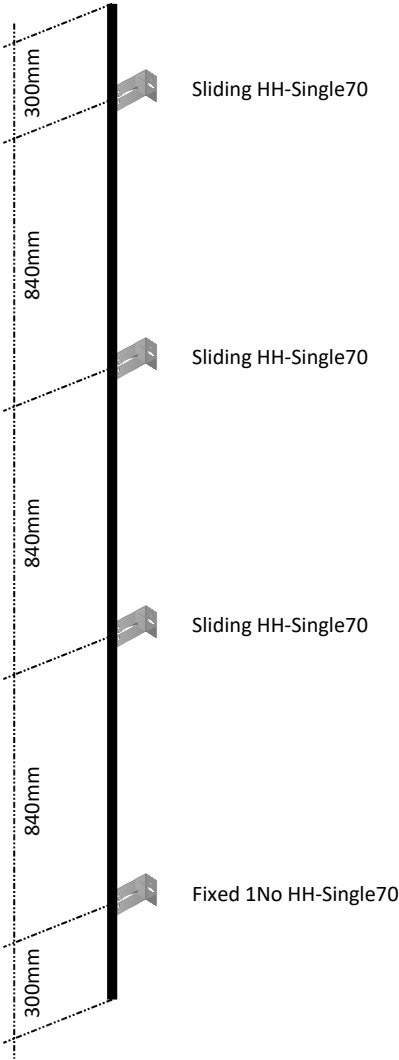
Dead load bracket	Type	HH-Single70	PASS	41%
	Number per rail	1		
	Fixings	2No Client to specify	Design to loading advised below	
	Peak load in fixing to structure:	Pullout = 0.91 kN ULS	Shear = 0.28 kN ULS	

Wind restraint bracket	Type	HH-Single70	PASS	11%
	Number per rail	3		
	Fixings	2No Client to specify	Design to loading advised below	
	Peak load in fixing to structure:	Pullout = 0.45 kN ULS		

NOTES	Maximum cavity for selected components	114 mm
	Minimum cavity for selected components	89 mm
	Current cavity zone	108 mm
	(Includes allowance for 0mm of panel fixings, 5mm thermal pad and 0mm top hat)	

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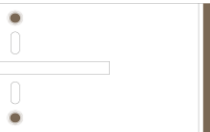


Rail length: 3120mm
Vertical rail: 60 Stem x 40 face x 2 L angle
Set @ max: 600mm cts

Note
Arrangement drawing is indicative only.
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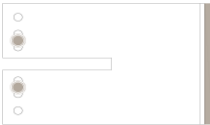
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Sliding Point (wind restraint & rail expansion)



Rail to bracket fixing:
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5 Wainwright Close, Churchfields Industrial Estate,
St Leonards on Sea, East Sussex, TN38 9PP

Project details

Project Name: **The Boatmans**
 Project ID: **SC23-02-015**
 Project Location: **Manchester M15 4QF**
 Designer Comments:

Author details

	By:	Date:
Authored:	IS	21/02/2023
Checked:		
Approved:		

Cladding buildup

Outer cladding:	Other	
Fixing system:	Face Fix	0 mm
Thickness:	10mm	Mass: 19.4 kg/m ²
Galvanised steel top hat:	None	Depth: 0 mm
Cavity width (face of sub-structure to back of panel):	108mm	
Thermal pad:	Thermostop	Thickness: 5 mm
Vertical rail:	60 Stem x 40 face x 2 L angle	
Brackets:	All 88mm high	
	Dead: HH-Single70	
	Sliding: HH-Single70	

Substrate

Type:	Fixing design by others - through holes	1.2 mm
	Design to loading advised below	

Loading

Design wind load to BS EN 1991-1-4 (WL):	1.17 kN/m ²	$\gamma_w =$	1.50
Check pressure and suction?:	Yes		
Design dead load (DL):	0.22 kN/m ²	$\gamma_g =$	1.35

Constraints

Main span design deflection limit δ_{ratio} :	L/200
Cantilever end design deflection limit δ_{cant} :	L/150
Maximum absolute deflection δ_{abs} :	2 mm

Geometry

Total height of vertical rail H_{rail} :	3.12 m
Rail horizontal spacing H_{cts} :	600 mm

Set out of brackets from base of rail:**Required number of spans: 5**

Base	Free	0.000 m
Restraint 1	Fixed	0.300 m
Restraint 2	Sliding	1.140 m

Restraint 3	Sliding	1.980 m
Restraint 4	Sliding	2.820 m
Top	Free	3.120 m

Component load resistances:

60 Stem x 40 face x 2 L angle vertical rails

Moment of inertia	$I_{y,rail}$	=	(refer to rail calculations)	7.51 cm ⁴
Moment resistance	$M_{c,Rd,rail}$	=	(refer to rail calculations)	65.54 Nm
Axial resistance	$N_{c,Rd,rail}$	=	(refer to rail calculations)	8.89 kN
Shear resistance	$V_{c,Rd,rail}$	=	(refer to rail calculations)	10.08 kN

HH-Single70 Dead load bracket

Compression resistance	$N_{c,Rd,DLB}$	=	(refer to bracket calculations)	8.47 kN
Tensile resistance	$N_{t,Rd,DLB}$	=	(refer to bracket calculations)	1.56 kN
Moment resistance	$M_{c,Rd,DLB}$	=	(refer to bracket calculations)	0.22 kNm
Shear resistance	$V_{c,Rd,DLB}$	=	(refer to bracket calculations)	1.37 kN
Fixing tensile resistance	$N_{t,fix,DLB}$	=	(fixing design by others)	0.00 kN
Fixing shear resistance	$V_{fix,DLB}$	=	(fixing design by others)	0.00 kN
Fixing moment resistance	$M_{fix,DLB}$	=	(fixing design by others)	0.00 kNm

HH-Single70 Sliding bracket

Compression resistance	$N_{c,Rd,SLB}$	=	(refer to bracket calculations)	11.78 kN
Tensile resistance	$N_{t,Rd,SLB}$	=	(refer to bracket calculations)	2.13 kN
Fixing tensile resistance	$N_{t,fix,SLB}$	=	(fixing design by others)	0.00 kN
Fixing shear resistance	$V_{c,Rd,SLB}$	=	(fixing design by others)	0.00 kN

Worst case rail tensile reaction allowable	$R_{max,t}$	=	$\min \{ V_{c,Rd,rail} ; N_{t,Rd,DLB} ; N_{t,fix,DLB} ; N_{t,fix,SLB} ; N_{t,Rd,SLB} \}$	1.56 kN
Worst case rail compressive reaction allowable	$R_{max,c}$	=	$\min \{ V_{c,Rd,rail} ; N_{c,Rd,DLB} ; N_{c,Rd,SLB} \}$	8.47 kN

Lateral line load on rails	w_{SLS}	=	$WL \cdot H_{ctS}$	0.70 kN/m
	w_{ULS}	=	$w_{ULS} \cdot Y_w$	1.06 kN/m

Basic analytical analysis:

Max span for rail deflection (single span)	=	$(384 \cdot E_{alu} \cdot I_{y,rail} / (5 \cdot \delta_{ratio} \cdot w_{sls}))^{1/3}$	1.42 m
Max span for rail abs. deflection (single span)	=	$(384 \cdot \delta_{abs} \cdot E_{alu} \cdot I_{y,rail} / (5 \cdot w_{sls}))^{1/4}$	1.03 m
Max span for rail deflection (double span)	=	$(185 \cdot E_{alu} \cdot I_{y,rail} / (\delta_{ratio} \cdot w_{sls}))^{1/3}$	1.90 m
Max span for rail abs. deflection (double span)	=	$(185 \cdot \delta_{abs} \cdot E_{alu} \cdot I_{y,rail} / (w_{sls}))^{1/4}$	1.29 m
Max span for rail deflection (multi span)	=	$(145 \cdot E_{alu} \cdot I_{y,rail} / (\delta_{ratio} \cdot w_{sls}))^{1/3}$	1.76 m
Max span for rail abs. deflection (multi span)	=	$(145 \cdot \delta_{abs} \cdot E_{alu} \cdot I_{y,rail} / (w_{sls}))^{1/4}$	1.21 m
Max span for rail moment	=	$(8 \cdot M_{c,Rd,rail} / (w_{uls}))^{1/2}$	0.70 m
Max span for rail moment (multi span)	=	$(10 \cdot M_{c,Rd,rail} / (w_{uls}))^{1/2}$	0.79 m
Max span for bracket pullout (single span)	=	$2 \cdot R_{max,t} / (w_{uls})$	2.95 m
Max span for bracket pullout (double span)	=	$8 \cdot R_{max,t} / (10 \cdot w_{uls})$	1.18 m
Max span for bracket pullout (multi span)	=	$10 \cdot R_{max,t} / (12 \cdot w_{uls})$	1.23 m

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Max span for bracket compression (single span)	=	$2 \cdot R_{\max,c} / (w_{uls})$	16.04 m
Max span for bracket compression (dble span)	=	$8 \cdot R_{\max,c} / (10 \cdot w_{uls})$	6.42 m
Max span for bracket compression (multi span)	=	$10 \cdot R_{\max,c} / (12 \cdot w_{uls})$	6.68 m

Therefore, limit the span to	$L_{\max}$	=	0.80 m
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Results from full analysis

Maximum cantilever deflection =	0.00 mm	< 2mm	PASS
Minimum cantilever deflection =	-0.02 mm	< 2mm	PASS
Maximum cantilever deflection ratio =		$L / 13102$	PASS
Maximum cantilever moment (ULS) =	0.00 Nm	< 65.54	PASS
Minimum cantilever moment (ULS) =	-47.52 Nm	< 65.54	PASS
Maximum main span deflection =	0.24 mm	< 2mm	PASS
Minimum main span deflection =	0 mm	< 2mm	PASS
Maximum main span deflection ratio =		$L / 3517$	PASS
Maximum main span moment (ULS) =	36.87 Nm	< 65.54	PASS
Minimum main span moment (ULS) =	-65 Nm	< 65.54	PASS

Number of dead load brackets required	I	PASS
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Basic Wind Load Analysis to BS EN 1991-1-4 & UK National Annex

Project post code: MI5 4QF
Site location: In town

Site altitude	A	=	=	34.00 m
Map wind speed	$V_{b,map}$	=	=	23.00 m/s
Height of building to eaves	Z	=	=	24.00 m
Distance to sea		=	=	50.00 km
Distance inside town		=	=	8.00 km
Terrain category		=	=	3
Surrounding obstructions	h_{dis}	=	=	5.00 m
Altitude factor	C_{alt}	=	$1 + 0.001(C_{gec} \times A)$	1.03
Direction factor	C_{dir}	=	worst case 240 degrees	1.00
Season factor	C_{season}	=	worst case	1.00
Probability factor	C_{prob}	=	worst case	1.00
Exposure factor	$C_e(z)$	=	UK NA to EN 1991-1-4, Figure NA.7	2.82
Town exposure correction factor	$C_{e,T}$	=	UK NA to EN 1991-1-4, Figure NA.8	1
Fundamental basic wind velocity	$V_{b,0}$	=	$C_{alt} \times V_{b,map}$	23.78 m/s
Basic velocity	V_b	=	$V_{b,0} \times C_{season} \times C_{prob} \times C_{dir}$	23.78 m/s
Basic velocity pressure	q_b	=	$0.613 \times V_b^2$	0.35 kN/m ²
Peak velocity pressure	q_p	=	$q_b \times C_e(z) \times C_{e,T}$	0.98 kN/m ²
Is funnelling present?	No			
Is the building envelope ventilated?	Yes		Rainscreen	
Internal pressure coefficient $C_{p,i}$	$C_{p,i}$	=	=	0.00
External pressure coefficient $C_{p,e}$	$C_{o,e}$	=	=	1.20
Net pressure coefficient $C_{p,net}$	$C_{p,net}$	=	$C_{p,i} + C_{p,e}$	1.20
Calculation of net positive pressure		=	$q_p \times C_{p,net}$	1.17 kN/m²

Sheeting Rail Design

Rail type	= 60 Stem x 40 face x 2 L angle			
Material	= 6063-T6			
Yield strength	f_0	=		= 160 N/mm ²
Ultimate strength	f_u	=		= 195 N/mm ²
Young's Modulus	E_{alu}	=		= 70000 N/mm ²
Density	ρ_{alu}	=		= 2700 kg/m ³
Material safety factors	γ_{M1}	=		= 1.1
	γ_{M2}	=		= 1.25
Buckling class	BC	=		= A
Gross cross section				
Stem Depth	D_s	=		= 60 mm
Face Width	W_f	=		= 40 mm
Stem Thickness	t_s	=		= 2 mm
Face Thickness	t_f	=		= 2 mm
Gross properties				
Area	A_g	=		= 196.00 mm ²
Inertia about y axis	I_y	=		= 7.51 cm ⁴
Inertia about z axis	I_z	=		= 2.77 cm ⁴
Radius of gyration in y axis	i_y	= $(I_y / A_g)^{0.5}$		= 19.57 mm
Radius of gyration in z axis	i_z	= $(I_z / A_g)^{0.5}$		= 11.90 mm
Distance to elastic neutral axis from edge of face	y_{gc}	=		= 8.76 mm
Distance to elastic neutral axis from base of stem	z_{gc}	=		= 41.24 mm
Elastic modulus about y axis	$W_{el,y}$	= $I_y / \max(z_{gc}; D_s - z_{gc})$		= 1.82 cm ³
Elastic modulus about z axis	$W_{el,z}$	= $I_z / \max(y_{gc}; W_f - y_{gc})$		= 0.89 cm ³
Reduced effective section properties				
Material strength parameter	Eps	= $(250/f_0)^{0.5}$		= 1.25
Reduced cross section in y-y bending - stem in compression - unreinforced unsymmetrical outstand element				
Tensile stress at face	σ_T	= $-\sigma_C (D_s - z_{gc}) / z_{gc}$		= -72.78
Stress ratio of ends of the stem	ψ	=		= -0.45
		EN 1999-1 Figure 6.2 Line B for outstand with		
Slenderness reduction	η	= peak compression at toe		= 1.00
Slenderness parameter of the stem	$\beta_{b,bc,stem}$	= $\eta D_s / t_s$		= 30.00
Maximum slendernesses for section classification	β_1	= $3 \times Eps$		= 3.75
(EN 1999-1-1:2007 Table 6.2)	β_2	= $4.5 \times Eps$		= 5.63
	β_3	= $6 \times Eps$		= 7.50
	$\beta_{b,bc,stem}$	> β_3		
Therefore, section is classified:	CLASS 4			
Determine effective section	C1	= (EN 1999-1-1:2007 Table 6.3)		= 10.00
	C2	= (EN 1999-1-1:2007 Table 6.3)		= 24.00
	$\rho_{b,bc,stem}$	= $\min\{(C1/(\beta/Eps)) - (C2/(\beta/Eps)^2); 120/(\beta/Eps)^2\}$		= 0.21
Effective thickness of compression segment of stem	$t_{eff,b,bc,stem}$	= $\rho_{b,bc,stem} \times t_s$		= 0.42 mm
Effective area	$A_{eff,b,bc}$	=		= 102.58 mm ²

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Effective inertia about y axis	$I_{y,eff,b,tc}$	=	=	2.34 cm ⁴
Effective distance to elastic NA from edge of face	$y_{gc,eff,b,tc}$	=	=	15.83 mm
Effective distance to elastic NA from base of stem	$z_{gc,eff,b,tc}$	=	=	51.93 mm
Effective elastic modulus about y axis	$W_{el,y,eff,b,tc}$	= I_y / z_{gc}	=	0.45 cm ³

Reduced cross section in y-y bending - face in compression - unreinforced unsymmetrical outstand element

Slenderness parameter of the face	$\beta_{b,tc,face}$	= Wf / t_f	=	20.00
Maximum slendernesses for section classification (EN 1999-1-1:2007 Table 6.2)	β_1	= $3 \times Eps$	=	3.75
	β_2	= $4.5 \times Eps$	=	5.63
	β_3	= $6 \times Eps$	=	7.50
	$\beta_{b,tc,face}$	> β_3		
Tensile stress at toe	σ_T	= $-\sigma_C \cdot z_{gc} / (D_s - z_{gc})$	=	-351.72
Stress ratio of ends of the stem	ψ	=	=	-2.20
Slenderness reduction	η	= EN 1999-1 Figure 6.2 Line A	=	0.25

Slenderness parameter of the compression part of the stem	$\beta_{b,tc,stem}$	= $\eta D_s / t_s$	=	7.50
Maximum slendernesses for section classification (EN 1999-1-1:2007 Table 6.2)	β_1	= $3 \times Eps$	=	3.75
	β_2	= $4.5 \times Eps$	=	5.63
	β_3	= $6 \times Eps$	=	7.50
	$\beta_{b,tc,stem}$	> β_3		

Therefore, section is classified:

CLASS 4

Determine effective section	CI_f	= (EN 1999-1-1:2007 Table 6.3)	=	10.00
	$C2_f$	= (EN 1999-1-1:2007 Table 6.3)	=	24.00
		$(CI_f / (\beta / Eps)) - (C2_f / (\beta / Eps)^2)$ but max		

	$\rho_{b,tc,face}$	= $120 / (\beta / Eps)^2$ for angle sections	=	0.47
Effective thickness of face	$t_{eff,b,tc,face}$	= $\rho_{b,tc,face} \times t_f$	=	0.94 mm

	CI_s	= (EN 1999-1-1:2007 Table 6.3)	=	10.00
	$C2_s$	= (EN 1999-1-1:2007 Table 6.3)	=	24.00
	$\rho_{b,tc,stem}$	= $(CI_s / (\beta / Eps)) - (C2_s / (\beta / Eps)^2)$	=	1.00

Effective thickness of stem part in compression	$t_{eff,b,tc,stem}$	= $\rho_{b,tc,face} \times t_f$	=	2.00 mm
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Effective area	$A_{eff,b,tc}$	=	=	154.56 mm ²
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Effective inertia about y axis	$I_{y,eff,b,tc}$	=	=	5.85 cm ⁴
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Effective distance to elastic NA from edge of face	$y_{gc,eff,b,tc}$	=	=	5.61 mm
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Effective distance to elastic NA from base of stem	$z_{gc,eff,b,tc}$	=	=	36.48 mm
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Effective elastic modulus about y axis	$W_{el,y,eff,b,tc}$	= $I_y / (D_s - z_{gc})$	=	2.49 cm ³
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Reduced cross section in compression

Adopt thicknesses previously calculated:

Effective thickness of stem	$t_{eff,c,stem}$	=	=	0.42 mm
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Effective thickness of face	$t_{eff,c,face}$	=	=	0.94 mm
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Effective area in compression	$A_{eff,c}$	=	=	61.15 mm ²
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Effective distance to elastic NA from edge of face	$y_{gc,eff,c}$	=	=	12.66 mm
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Effective distance to elastic NA from edge of stem	$z_{gc,eff,c}$	=	=	47.14 mm
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Flexural buckling - major axis only as minor axis is restrained by cladding

Effective length in y axis	$Le_{c,y}$	=	=	1000.00 mm
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Relative slenderness in y axis	$\lambda_{f,y}$	= $Le_{c,y} \times ((A_{eff,c} / A_g) \cdot (f_0 \times E_{alu}))^{0.5} / (i_y \times \pi)$	=	0.69
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Buckling plateau limit	λ_0	= EN 1999-1 Table 6.6	=	0.10
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5 Wainwright Close, Churchfields Industrial Estate,
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Imperfection factor	α	= EN 1999-1 Table 6.6	=	0.20
	ϕ_y	=	=	0.80
Flexural buckling reduction in y axis	$\chi_{f,y}$	= $1 / (\phi_y + (\phi_y^2 - \lambda_y^2)^{0.5})$	=	0.84

Section in major axis shear

Shear slenderness	λ_s	= D_s / t_s	=	30.00
Limiting slenderness	$\lambda_{s,max}$	= $39 \times Eps$	=	48.75
Web is non-slender				

Section properties

Loading due to wind may be in either direction therefore
consider worst case moment resistance.

	$M_{cy,Rd}$	= $\min\{W_{el,y,eff,b,tc} ; W_{el,y,eff,b,bc}\} \times f_0 / \gamma_{M1}$	=	65.54 Nm
Shear resistance	V_{Rd}	= $D_s \times t_s \times f_0 / (3^{0.5} \times \lambda_{M1})$	=	10.08 kN
Compression resistance	$N_{c,Rd}$	= $A_{eff,c} \times f_0 / \gamma_{M1}$	=	8.89 kN
Buckling resistance	$N_{b,Rd}$	= $A_{eff,c} \times f_0 \times \chi_{f,y} / \gamma_{M1}$	=	7.43 kN

Bracket Design

Dead fix bracket design

Geometry

Zone for rail and bracket	z_b	=	=	103 mm
Bracket to be checked:	HH-Single70			
Bracket height	h_b	=	=	88 mm
Thickness	t_b	=	=	3 mm
Outstand leg length	L_1	=	=	70 mm
Return leg length	L_2	=	=	40 mm
Bottom fold	L_3	=	=	0 mm

Material grade

6063-T6

Yield strength	f_0	=	=	160 N/mm ²
Ultimate strength	f_u	=	=	195 N/mm ²
Young's Modulus	E_{alu}	=	=	70000 N/mm ²
Density	ρ_{alu}	=	=	2700 kg/m ³
Material safety factors	γ_{M1}	=	=	1.1
	γ_{M2}	=	=	1.25
Buckling class	BC	=	=	A
Material strength parameter	Eps	=	=	$(250/f_0)^{0.5}$ 1.25

Gross properties

Area	A_g	=	=	264.00 mm ²
Inertia about y axis	I_y	=	=	17.04 cm ⁴
Inertia about z axis	I_z	=	=	0.02 cm ⁴
Radius of gyration in y axis	i_y	=	=	$(I_y / A_g)^{0.5}$ 25.40 mm
Radius of gyration in z axis	i_z	=	=	$(I_z / A_g)^{0.5}$ 0.87 mm
Distance to elastic neutral axis from edge of face	y_{gc}	=	=	1.50 mm
Distance to elastic neutral axis from base of bracket	z_{gc}	=	=	44.00 mm
Elastic modulus about y axis	$W_{el,y}$	=	=	$I_y / \max(z_{gc}; h_b - z_{gc})$ 3.87 cm ³
Elastic modulus about z axis	$W_{el,z}$	=	=	$I_z / \max(y_{gc}; L_3 - y_{gc})$ 0.13 cm ³

Capacity for pullout due to wind suction

Section modulus of back leg	$W_{pl,L2}$	=	$h_b \cdot t_b^2 / 4$	=	198 mm ³
Moment capacity of back leg	$M_{c,Rd,L2}$	=	$W_{pl,L2} \cdot f_0 / \gamma_{M1}$	=	28.80 Nm
Pull capacity of bracket	$N_{p,Rd,L2}$	=	$M_{c,Rd,L2} / ((L_2 \cdot 0.5) - (t_b / 2))$	=	1.56 kN

Capacity for bending due to dead load

Outstand leg effective section

Tensile stress at face	σ_T	=	$-\sigma_C (h_b - z_{gc}) / z_{gc}$	=	-160.00 N/mm ²
Stress ratio of ends of the leg	ψ	=	=	=	-1.00
	EN 1999-1 Figure 6.2 Line A for outstand				
Slenderness reduction	η	=	with peak compression at toe	=	1.00
Slenderness parameter of the stem	$\beta_{c,L1}$	=	$\eta h_b / t_b$	=	29.33

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St Leonards on Sea, East Sussex, TN38 9PP

Maximum slendernesses for section classification
(EN 1999-1-1:2007 Table 6.2)

$$\begin{aligned}\beta_1 &= 3 \times Eps &= 3.75 \\ \beta_2 &= 4.5 \times Eps &= 5.63 \\ \beta_3 &= 6 \times Eps &= 7.50 \\ \beta_{c,L1} &> \beta_3\end{aligned}$$

Therefore, section is classified:

CLASS 4

Determine effective section

$$\begin{aligned}C1 &= (\text{EN 1999-1-1:2007 Table 6.3}) &= 10.00 \\ C2 &= (\text{EN 1999-1-1:2007 Table 6.3}) &= 24.00 \\ &\min\{(C1/(\beta/Eps)) - (C2/(\beta/Eps)^2); \\ \rho_{c,L1} &= 120/(\beta/Eps)^2 &= 0.38 \\ t_{\text{eff},c,L1} &= \rho_{c,L1} \times t_b &= 1.15 \text{ mm}\end{aligned}$$

Effective thickness of outstand leg

Base fold leg effective section (if applicable)

Stress ratio of ends of the leg

$$\Psi = (\text{Uniform compression}) = 1.00$$

Slenderness reduction

$$\eta = (\text{Uniform compression}) = 1.00$$

Slenderness parameter of the stem

$$\beta_{c,L3} = \eta L_3 / t_b = 0.00$$

Maximum slendernesses for section classification
(EN 1999-1-1:2007 Table 6.2)

$$\begin{aligned}\beta_1 &= 3 \times Eps &= 3.75 \\ \beta_2 &= 4.5 \times Eps &= 5.63 \\ \beta_3 &= 6 \times Eps &= 7.50 \\ \beta_{c,L3} &< \beta_1\end{aligned}$$

Therefore, section is classified:

CLASS I

Section is fully effective

$$\begin{aligned}C1 &= (\text{EN 1999-1-1:2007 Table 6.3}) &= \text{N/A} \\ C2 &= (\text{EN 1999-1-1:2007 Table 6.3}) &= \text{N/A} \\ &\min\{(C1/(\beta/Eps)) - (C2/(\beta/Eps)^2); \\ \rho_{c,L3} &= 120/(\beta/Eps)^2 &= 1.00 \\ t_{\text{eff},c,L3} &= \rho_{c,L3} \times t_b &= 0.00 \text{ mm}\end{aligned}$$

Effective thickness of base fold

Shape properties

Effective inertia of bracket

$$I_{y,L1} = 6.52 \text{ cm}^4$$

Distance to elastic neutral axis from base of bracket

$$z_{\text{eff},b} = 44.00 \text{ mm}$$

Elastic modulus of outstand leg

$$W_{\text{el,eff},L1} = 1481.25 \text{ mm}^3$$

Moment capacity of outstand leg

$$M_{c,Rd,L1} = W_{\text{el},L2} \cdot f_0 / \gamma_{m1} = 215.45 \text{ Nm}$$

Vertical load capacity of bracket

$$V_{d,Rd,L1} = M_{c,Rd,L1} / L_1 = \underline{\underline{3.08 \text{ kN}}}$$

Capacity for compression due to wind pressure

Outstand leg effective section

Stress ratio of ends of the leg

$$\Psi = (\text{Uniform compression}) = 1.00$$

Slenderness reduction

$$\eta = (\text{Uniform compression}) = 1.00$$

Slenderness parameter of the stem

$$\beta_{c,L1} = \eta h_b / t_b = 29.33$$

Maximum slendernesses for section classification
(EN 1999-1-1:2007 Table 6.2)

$$\begin{aligned}\beta_1 &= 3 \times Eps &= 3.75 \\ \beta_2 &= 4.5 \times Eps &= 5.63 \\ \beta_3 &= 6 \times Eps &= 7.50 \\ \beta_{c,L1} &> \beta_3\end{aligned}$$

Therefore, section is classified:

CLASS 4

Determine effective section

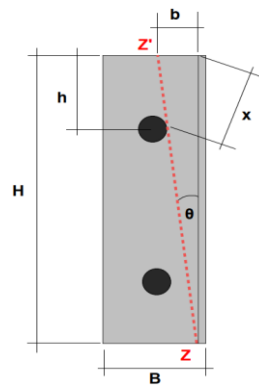
$$\begin{aligned}C1 &= (\text{EN 1999-1-1:2007 Table 6.3}) &= 10.00 \\ C2 &= (\text{EN 1999-1-1:2007 Table 6.3}) &= 24.00 \\ &\min\{(C1/(\beta/Eps)) - (C2/(\beta/Eps)^2); \\ \rho_{c,L1} &= 120/(\beta/Eps)^2 &= 0.38\end{aligned}$$

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Effective thickness of outstand leg	$t_{eff,c,L1}$	$= \rho_{c,L1} \times t_b$	$=$	1.15 mm
<u>Base fold leg effective section (if applicable)</u>				
Stress ratio of ends of the leg	Ψ	$=$ (Uniform compression)	$=$	1.00
Slenderness reduction	η	$=$ (Uniform compression)	$=$	1.00
Slenderness parameter of the stem	$\beta_{c,L3}$	$= \eta L_3 / t_b$	$=$	0.00
Maximum slendernesses for section classification (EN 1999-1-1:2007 Table 6.2)	β_1	$= 3.5 \times Eps$	$=$	3.75
	β_2	$= 4.5 \times Eps$	$=$	5.63
	β_3	$= 6 \times Eps$	$=$	7.50
	$\beta_{c,L3}$	$< \beta_1$		
	CLASS I			
Therefore, section is classified:	C1	$=$ (EN 1999-1-1:2007 Table 6.3)	$=$	N/A
Section is fully effective	C2	$=$ (EN 1999-1-1:2007 Table 6.3)	$=$	N/A
		$\min\{(C1/(\beta/Eps)) - (C2/(\beta/Eps)^2);$		
	$\rho_{c,L3}$	$= 120/(\beta/Eps)^2\}$	$=$	1.00
Effective thickness of base fold	$t_{eff,c,L3}$	$= \rho_{c,L3} \times t_b$	$=$	0.00 mm
<u>Shape properties</u>				
Effective area	$A_{eff,c,L1}$	$= h_b \cdot t_{eff,c,L1}$	$=$	100.99 mm ²
Effective inertia about y axis	$I_{y,eff,c,L1}$	$=$	$=$	6.52 cm ⁴
Effective distance to elastic NA from edge of face	$y_{gc,eff,c,L1}$	$=$	$=$	0.57 mm
Effective distance to elastic NA from base of stem	$z_{gc,eff,c,L1}$	$=$	$=$	44.00 mm
Effective elastic modulus about y axis	$W_{el,y,c,L1}$	$= I_y / z_{gc}$	$=$	1.48 cm ³
<i>Flexural buckling</i>				
Effective length in y axis	$Le_{c,y}$	$=$	$=$	103.00 mm
Effective length in z axis	$Le_{c,z}$	$=$	$=$	103.00 mm
Relative slenderness in y axis	$\lambda_{f,y}$	$= Le_{c,y} \times (A_{eff,c} / A_g) \cdot (f_0 \times E_{alul})^{0.5} / (I_y \times \pi)$	$=$	0.04
Relative slenderness in z axis	$\lambda_{f,z}$	$= Le_{c,z} \times (A_{eff,c} \times f_0) / (A_g \times E)^{0.5} / (I_z \times \pi)$	$=$	1.12
Buckling plateau limit	λ_0	$=$ EN 1999-1 Table 6.6	$=$	0.10
Imperfection factor	α	$=$ EN 1999-1 Table 6.6	$=$	0.20
	ϕ_y	$=$	$=$	0.49
	ϕ_z	$=$	$=$	1.23
Flexural buckling reduction in y axis	$\chi_{f,y}$	$= 1 / (\phi_y + (\phi_y^2 - \lambda_y^2)^{0.5})$	$=$	1.00
Flexural buckling reduction in z axis	$\chi_{f,z}$	$= 1 / (\phi_z + (\phi_z^2 - \lambda_z^2)^{0.5})$	$=$	0.58
Compressive resistance of the outstand leg(s)	$N_{b,Rd,L1}$	$= \min[\chi_{f,y}; \chi_{f,z}] \cdot A_{eff,c,L1} \cdot f_0 / \gamma_{MI}$	$=$	8.47 kN

Bending resistance of return leg



Bending about Z-Z'

Fixing head diameter	f_h	=		=	10 mm
Distance to top fixing from top of bracket	h	=		=	24.00 mm
Distance from fixing head to outstand leg	b	=	$B/2 - (t_b - f_h/2)$	=	12.00 mm
Distance from top corner of bracket to edge of fixing	x	=	$(b^2 + h^2)^{0.5}$	=	26.83 mm
Angle of yield line relative to outstand leg	θ	=	$\tan^{-1}(b/(H-h))$	=	0.19 rads
Length of yield line Z-Z'	L_e	=	$H/\cos\theta$	=	89.53 mm
Section modulus	$W_{pl,y,l}$	=	$L_e \cdot t^2 / 4$	=	201.45 mm ³
Moment capacity	$M_{c,y,l}$	=	$W_{pl,y,l} \cdot f_0 / \gamma_{M1}$	=	29.30 Nm
Maximum vertical load for offset e	F_{max}	=	$M_{c,y,l} \cdot H / (x \cdot e) [e = e_{max} = L]$	=	1.37 kN

Shear resistance of the outstand leg(s)

Shear slenderness	λ_s	=	h_b / t_b	=	29.33
Limiting slenderness	$\lambda_{s,max}$	=	$39 \times E_{ps}$	=	48.75
Web is non-slender					
Revised shear slenderness	λ_s	=	$0.35 \cdot h_b / t_b \cdot (f_0 / E)^{0.5}$	=	0.49
	η	=	$0.7 + 0.35 (f_0 / f_u)$	=	0.99
Reduction factor	ρ_v	=	BS EN 1999-1-1 cl 6.2.6.2(b)	=	0.80
Shear resistance	V_{Rd}	=	$\rho_v \times h_b \times t_b \times f_0 / (3^{0.5} \times \lambda_{M1})$	=	17.74 kN

Fixings to structure

Fixing to: Fixing design by others - through holes

Fixing specification: Client to specify

Number of fixings:

2

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Fixing group

Pullout resistance

Shear resistance

Moment resistance by row

 d_n Arm

1 - Bottom fixing

24mm

2

64mm

3

0mm

4

0mm

Dead load applied to bracket(s)

$$F_v = H_{rail} \cdot DL \cdot \gamma_g = 0.56 \text{ kN}$$

Lateral load applied to bracket(s)

$$F_h = (\text{from analysis}) = 0.74 \text{ kN}$$

Vertical moment applied to bracket

$$M_v = F_v \cdot L_I = 39.29 \text{ Nm}$$

Max pullout on top fixing

$$F_{Nmax} = M_v / \sum[d_n^2 / d_{max}] + F_h / n = 0.91 \text{ kN}$$

Max shear on fixing

$$F_{Vmax} = F_v / n = 0.28 \text{ kN}$$

Fixing to rail

Bearing capacity of 4.8mm dia fixing

$$V_{Rd,r,fix} = 2.25 \text{ kN}$$

Number of fixings

$$N_{r,fix} = 2$$

Total resultant shear in fixings

$$V_{Ed,fix} = 0.93 \text{ kN}$$

Fixing utilisation

$$= \underline{\underline{21\%}}$$

Overall worst case bracket result

$$= \underline{\underline{41\%}}$$

Minimum number of dead fix brackets to achieve fixing

$$= \underline{\underline{1}}$$

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St Leonards on Sea, East Sussex, TN38 9PP

Restraint fix bracket design

Geometry

Zone for rail and bracket	z_b	=		=	103 mm
Bracket to be checked:			HH-Single70		
Bracket height	h_b	=		=	88 mm
Thickness	t_b	=		=	3 mm
Outstand leg length	L_1	=		=	70 mm
Return leg length	L_2	=		=	40 mm
Bottom fold	L_3	=		=	0 mm

Material grade

6063-T6

Yield strength	f_0	=		=	160 N/mm ²
Ultimate strength	f_u	=		=	195 N/mm ²
Young's Modulus	E_{alu}	=		=	70000 N/mm ²
Density	ρ_{alu}	=		=	2700 kg/m ³
Material safety factors	γ_{M1}	=		=	1.1
	γ_{M2}	=		=	1.25
Buckling class	BC	=		=	A
Material strength parameter	Eps	=	$(250/f_0)^{0.5}$	=	1.25

Gross properties

Area	A_g	=		=	264.00 mm ²
Inertia about y axis	I_y	=		=	17.04 cm ⁴
Inertia about z axis	I_z	=		=	0.02 cm ⁴
Radius of gyration in y axis	i_y	=	$(I_y / A_g)^{0.5}$	=	25.40 mm
Radius of gyration in z axis	i_z	=	$(I_z / A_g)^{0.5}$	=	0.87 mm
Distance to elastic neutral axis from edge of face	y_{gc}	=		=	1.50 mm
Distance to elastic neutral axis from base of bracket	z_{gc}	=		=	44.00 mm
Elastic modulus about y axis	$W_{el,y}$	=	$I_y / \max(z_{gc}; D_s - z_{gc})$	=	3.87 cm ³
Elastic modulus about z axis	$W_{el,z}$	=	$I_z / \max(y_{gc}; W_f - y_{gc})$	=	-0.13 cm ³

Capacity for pullout due to wind suction

Check back leg for bending

Plastic modulus of back leg	$W_{pl,L2}$	=	$h_b \cdot t_b^2 / 4$	=	198 mm ³
Moment capacity of back leg	$M_{c,Rd,L2}$	=	$W_{pl,L2} \cdot f_0 / \gamma_{M1}$	=	28.80 Nm
Pull capacity of bracket	$N_{p,Rd,L2}$	=	$M_{c,Rd,L2} / ((L_2 \cdot 0.5) - (t_b / 2))$	=	2.13 kN

Capacity for compression due to wind pressure

Check outstand leg(s) for compression

Outstand leg effective section

Stress ratio of ends of the leg	Ψ	=	(Uniform compression)	=	1.00
Slenderness reduction	η	=	(Uniform compression)	=	1.00
Slenderness parameter of the stem	$\beta_{c,L1}$	=	$\eta h_b / t_b$	=	29.33
Maximum slendernesses for section classification	β_1	=	$3 \times Eps$	=	3.75
(EN 1999-1-1:2007 Table 6.2)	β_2	=	$4.5 \times Eps$	=	5.63
	β_3	=	$6 \times Eps$	=	7.50

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5 Wainwright Close, Churchfields Industrial Estate,
St Leonards on Sea, East Sussex, TN38 9PP

	$\beta_{c,L1}$	$> \beta_3$	
Therefore, section is classified:	CLASS 4		
Determine effective section	C1	= (EN 1999-1-1:2007 Table 6.3)	= 10.00
	C2	= (EN 1999-1-1:2007 Table 6.3)	= 24.00
		$\min\{(C1/(\beta/Eps)) - (C2/(\beta/Eps)^2);$	
	$\rho_{c,L1}$	= $120/(\beta/Eps)^2\}$	= 0.38
Effective thickness of outstand leg	$t_{eff,c,L1}$	= $\rho_{c,L1} \times t_b$	= 1.15 mm
<u>Base fold leg effective section (if applicable)</u>			
Stress ratio of ends of the leg	Ψ	= (Uniform compression)	= 1.00
Slenderness reduction	η	= (Uniform compression)	= 1.00
Slenderness parameter of the stem	$\beta_{c,L3}$	= $\eta L_3 / t_b$	= 0.00
Maximum slendernesses for section classification	β_1	= $3 \times Eps$	= 3.75
(EN 1999-1-1:2007 Table 6.2)	β_2	= $4.5 \times Eps$	= 5.63
	β_3	= $6 \times Eps$	= 7.50
	$\beta_{c,L3}$	$< \beta_1$	
Therefore, section is classified:	CLASS 1		
Section is fully effective	C1	= (EN 1999-1-1:2007 Table 6.3)	= N/A
	C2	= (EN 1999-1-1:2007 Table 6.3)	= N/A
		$\min\{(C1/(\beta/Eps)) - (C2/(\beta/Eps)^2);$	
	$\rho_{c,L3}$	= $120/(\beta/Eps)^2\}$	= 1.00
Effective thickness of base fold	$t_{eff,c,L3}$	= $\rho_{c,L3} \times t_b$	= 0.00 mm
<u>Shape properties</u>			
Effective area	$A_{eff,c,L1}$	= $h_b \cdot t_{eff,c,L1}$	= 100.99 mm ²
Effective inertia about y axis	$I_{y,eff,c,L1}$	=	= 6.52 cm ⁴
Effective distance to elastic NA from edge of face	$y_{gc,eff,c,L1}$	=	= 0.57 mm
Effective distance to elastic NA from base of stem	$z_{gc,eff,c,L1}$	=	= 44.00 mm
Effective elastic modulus about y axis	$W_{el,y,c,L1}$	= I_y / z_{gc}	= 1.48 cm ³
<i>Flexural buckling</i>			
Effective length in y axis	$Le_{c,y}$	=	= 70.00 mm
Effective length in z axis	$Le_{c,z}$	=	= 70.00 mm
Relative slenderness in y axis	$\lambda_{f,y}$	= $Le_{c,y} \times (A_{eff,c} / A_g) \cdot (f_0 \times E_{alul})^{0.5} / (I_y \times \pi)$	= 0.03
Relative slenderness in z axis	$\lambda_{f,z}$	= $Le_{c,z} \times (A_{eff,c} \times f_0) / (A_g \times E)^{0.5} / (I_z \times \pi)$	= 0.76
Buckling plateau limit	λ_0	= EN 1999-1 Table 6.6	= 0.10
Imperfection factor	α	= EN 1999-1 Table 6.6	= 0.20
	ϕ_y	=	= 0.49
	ϕ_z	=	= 0.86
Flexural buckling reduction in y axis	$\chi_{f,y}$	= $1 / (\phi_y + (\phi_y^2 - \lambda_y^2)^{0.5})$	= 1.00
Flexural buckling reduction in z axis	$\chi_{f,z}$	= $1 / (\phi_z + (\phi_z^2 - \lambda_z^2)^{0.5})$	= 0.80
Compressive resistance of the outstand leg(s)	$N_{b,Rd,L1}$	= $\min[\chi_{f,y}; \chi_{f,z}] \cdot A_{eff,c,L1} \cdot f_0 / \gamma_{MI}$	= 11.78 kN

Fixing to substrate:

Fixing to:

Fixing design by others - through holes

Fixing specification:

Client to specify

Number of fixings:

2

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Fixing pullout resistance	$N_{Rd,fix}$	=	=	0.00 kN
Fixing shear resistance	$V_{Rd,fix}$	=	=	0.00 kN
Fixing resultant load limit	$F_{Rd,fix}$	=	=	0.00 kN

Lateral load applied to bracket(s)	F_h	= (from analysis)	=	0.91 kN
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Client to specify fixing to suit loads below:

Pullout per fixing (ULS)	N_{fix}	= F_h / n	=	0.45 kN
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Fixing to rail

Bearing capacity of 4.8mm dia fixing	$V_{Rd,r,fix}$	=	=	2.25 kN
Number of fixings	$N_{r,fix}$	=	=	2
Total resultant shear in fixings	$V_{Ed,fix}$	=	=	0.91 kN
Fixing utilisation			=	<u><u>20%</u></u>