APOLLO CRADLES LTD
X- BEAM
CALCULATIONS

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Brief

The brief is to prepare calculated values for the capacity of the Apollo X-BEAM to BS 8118.

The beams are fabricated from tube extrusions in aluminium alloy 6082 T6

The geometry of the beam is as shown on drawing No F0021/003

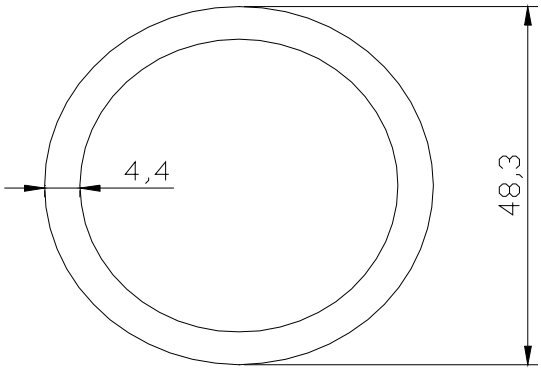
The beams have been tested and the results are compared in the summary

Material

The alloy 6082T6 has the following properties

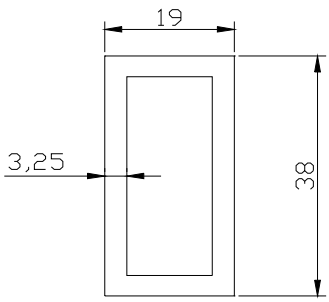
p_0=	255	N/mm2
p_a=	280	N/mm2
p_v=	155	N/mm2

Main boom and verticals



Area:		606.83	mm2
Bounding box:	X:	-24.15 - 24.15	mm
	Y:	-24.15 - 24.15	mm
Moments of inertia:	X:	147654.64	mm4
	Y:	147654.64	mm4
Radii of gyration:	X:	15.60	mm
	Y:	15.60	mm
Elastic Modulus	X:	6114.06	mm3
	Y:	6114.06	mm3
Plastic Modulus	X:	8253.99	mm3
	Y:	8253.99	mm3

Diagonals



Area:		328.25	mm2
Bounding box:	X:	-9.5 -- 9.5	mm
	Y:	-19.00 -- 19.00	mm
Moments of inertia:	X:	54322.46	mm4
	Y:	16593.21	mm4
Radii of gyration:	X:	12.86	mm
	Y:	7.11	mm
Elastic Modulus	X:	2859.08	mm3
	Y:	1746.65	mm3
Plastic Modulus	X:	3758.22	mm3
	Y:	2199.03	mm3

Classification

4.3.1

β= 3*((D/t)^0.5)
= 3*(((48.3-4.4)/4.4)^0.5)
= 9.48

ε= (250/p0)^0.5
= (250/255)^0.5
= 0.99

β1= 15ε
15*0.99
14.85
> 9.48

Section is compact

Bending capacity 4.5.2.2

Mrs= poSn/γm

po= 255N/mm2
Sn= 8.25cm3
γm= 1.2

= 255*8.25/1200
= **1.74 kNm**

Shear 4.5.3.2

Vrs= pvAv/γm

pv= 155N/mm2
Av= 0.6A
= 0.6*606.83
= 364.1mm2
γm= 1.2

=155*364.1/1200
= **47.03 kN**

Lateral Torsional Buckling

No check required for CHS

Tension 4.6

for General Tension

Prs= poA/γm

po= 255N/mm2
A= 606.83mm2
γm= 1.3

= 255*606.83/1300
= **119.03** kN

For local at splice

Prs paAn/γm

pa= 280N.mm2
An= A-2dt
606.83-2*14*4.4
483.63mm2
γm= 1.3

= 280*483.63/1300
= **104.17 kN**

Compression

4.7

Pr= psA/γm

for 1m bracing

L= 950.00 m

r= 15.6 mm

λ= KL/r K= 0.7

0.7*950/15.6

42.63

Fig 4.10b gives ps= 184.00 N/mm2

A= 606.83mm2

γm= 1.3

Pr= 184*606.83/1300

= **85.89 kN**

Classification 4.3.1

β= 3*((D/t)^0.5)
= 3*(((38-3.25)/3.25)^0.5)
= 9.81

ε= (250/p0)^0.5
= (250/255)^0.5
= 0.99

β1= 15ε
15*0.99
14.85
> 9.81

Section is compact

Bending capacity 4.5.2.2

Mrs= poSn/γm

po= 255N/mm2
Sn= 3.76cm3
γm= 1.3

= 255*3.76/1300
= **0.74 kNm**

Shear 4.5.3.2

Vrs= pvAv/γm

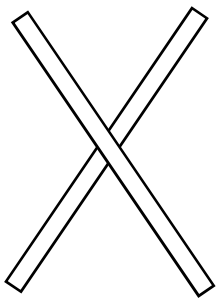
pv= 155N/mm2
Av= 0.8NDt
= 0.8*2*38*3.25
= 197.6mm2
γm= 1.3

=155*197.6/1300
= **23.56 kN**

Lateral Torsional Buckling

overall length L= SQRT(652^2+425^2)
778.29

length to brace point is L/2



Le= 0.85*778.29/2
330.77

λ= Le/ry
= 330.77/7.11
= 47

ps= 220 N/mm2

Mrx= psS/γ_m

S= 3.76cm3
γm= 1.2

= 220*3.76/1200
= **0.69 kNm**

Tension 4.6

for General Tension only (no local holes)

Prs= poA/γm po= 255N/mm2
A= 328.3mm2
γm= 1.2

= 255*328.3/1200
= **69.76 kN**

Compression

4.7

Pr= psA/γm

L= 0.338 m
r= 7.11 mm
λ= KL/r K= 0.7
= 0.7*338/7.11
= 33.28

Fig 4.10b gives ps= 182.00 N/mm2

A= 328.3mm2
γm= 1.2

Pr= 182*328.3/1200
= **49.79 kN**

for local squashing Prs= paAe/γm pa= 280N/mm2
Ae= 164.2mm2
γm= 1.2

= 280*164.2/1200
= **38.31 kN**

Use local squashing value

Tension 4.6

for General Tension only (no local holes)

Prs= $p_o A/\gamma_m$ po= 255N/mm2
A= 328.3mm2
γ_m= 1.3

= 255*328.3/1300
= **64.40 kN**

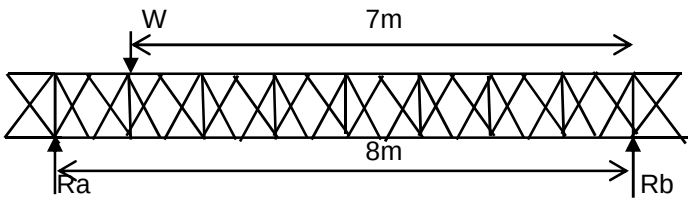
for local softening Prs= $p_a A_e/\gamma_m$ pa= 280N/mm2
Ae= 164.2mm2
γ_m= 1.2

= 280*164.2/1200
= **38.31 kN**

Load Case 2 Load at end (note Load case 1 was not used for analyisis - self weight only)

10kN applied 1m from end

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	Mrs	1.74	0.06	28.94
	Shear	Vrs	47.03	0.18	261.28
	Tension	Prs	104.17	16.75	6.22
	Compression	Pry	85.89	16.13	5.32
		coexist M		0.007	
	Combined	P/Prs+M/Mrs<1		0.19	5.21
Vertical	Moment	Mrs	1.74	0.02	86.81
	Shear	Vrs	47.03	0.05	940.59
	Tension	Prs	119.03	0.00	
	Compression	Pry	85.89	5.8	14.81
		coexist M		0.02	
	Combined	P/Prs+M/Mrs<1		0.08	12.65
Diagonal	Tension	Prs	38.31	7.08	5.41
	Compression	Pry	38.31	7.4	5.18
				Factor	**5.18**



Max shear Ra= W*7/8

so for ultimate condition

W= **1.33*10**

13.30 kN

apply factor from above

Wf= 13.3*5.18

69.05 kN

so reaction at A is max shear

Ultimate Ra= Wf*7/8

Ultimate shear= **60.42 kN**

and for allowable value

allowable Shear= 60.42/1.33

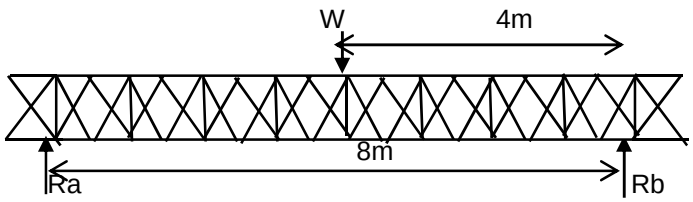
= **45.43** **kN**

Shear values	**Ultimate**	**60.42 kN**
	Allowable	**45.43 kN**

Load Case 3 Load at middle

10kN applied at centre

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	Mrs	1.74	0.07	24.80
	Shear	Vrs	47.03	0.1	470.30
	Tension	Prs	104.17	36.68	2.84
	Compression	Pry	85.89	36.09	2.38
		coexist M		0.07	
	Combined	P/Prs+M/Mrs<1		0.46	2.17
Vertical	Moment	Mrs	1.74	0.02	86.81
	Shear	Vrs	47.03	0.06	783.83
	Tension	Prs	119.03	0	
	Compression	Pry	85.89	5.6	15.34
		coexist M		0	
	Combined	P/Prs+M/Mrs<1		0.07	15.34
Diagonal	Tension	Prs	38.31	4.5	8.51
	Compression	Pry	38.31	4.6	8.33
				Factor	**2.17**



Max Moment= ML/4

so for ultimate condition

W= **1.33*10**

13.30 kN

apply factor from above

Wf= 13.3*2.17

28.93

so maximum moment is as above

Ultimate Mu= Wf*8/4

28.93*8/4

57.86 kN

and for allowable value

allowable max moment= 57.86/1.33

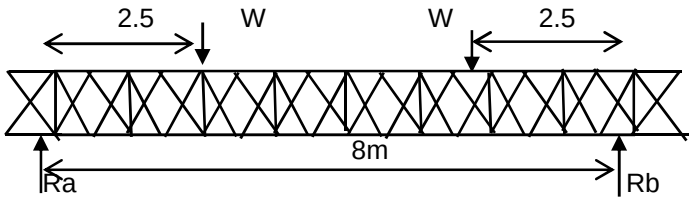
= **43.50** **kN**

Moment values	**Ultimate**	**57.86 kN**
	Allowable	**43.50 kN**

Load Case 4 Load at third points

10kN applied at each of the two third points

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	Mrs	1.74	0.07	24.80
	Shear	Vrs	47.03	0.18	261.28
	Tension	Prs	104.17	50.18	2.08
	Compression	Pry	85.89	48.3	1.78
		coexist M		0.04	
	Combined	P/Prs+M/Mrs<1		0.59	1.71
Vertical	Moment	Mrs	1.74	0.05	34.72
	Shear	Vrs	47.03	0.12	391.91
	Tension	Prs	119.03	2.37	50.22
	Compression	Pry	85.89	6.14	13.99
		coexist M		0.02	
	Combined	P/Prs+M/Mrs<1		0.08	12.05
Diagonal	Tension	Prs	38.31	8.68	4.41
	Compression	Pry	38.31	11.9	3.22
				Factor	**1.71**



Max Moment= 2.5W

so for ultimate condition

W= **1.33*10**

13.30 kN

apply factor from above

Wf= 13.3*1.71

22.79

so maximum moment is as above

Ultimate Mu= Wf*2.5

2.5*22.79

56.99 kN

and for allowable value

allowable max moment= 56.99/1.33

= **42.85** **kN**

Moment values	**Ultimate**	**56.99 kN**
	Allowable	**42.85 kN**

Test Results

The test results for mid point and third point moments agree closely with the calculated values

Allowable moment	**42.9**	**kNm**
Ultimate moment	**57.0**	**kNm**

Selected results

From calculated values confirmed by test results for bracing at 1m intervals

Max moment on the beam is

Allowable moment	**42.9**	**kNm**
Ultimate moment	**57.0**	**kNm**

and Maximum Shear is

Allowable shear	**45.4**	**kN**
Ultimate shear	**60.4**	**kN**

For simply supported Apollo X-BEAM with a compression chord restraint at 1m intervals

Allowable Bending Moment	42.9 kNm
Allowable Shear	45.4 kN

Allowable loads for load distributions

Maximum allowable values		3	4	5	6	7	8	9	10	11	12
Uniformly Distributed load	kN/m	*30.3*	*21.5*	13.7	9.5	7.0	5.4	4.2	3.4	2.8	2.4
Total UDL	kN	*90.8*	*85.8*	68.6	57.2	49.0	42.9	38.1	34.3	31.2	28.6
Single point load (mid Point)	kN	57.2	42.9	34.3	28.6	24.5	21.5	19.1	17.2	15.6	14.3
Two point loads (third points)	Each kN	42.9	32.2	25.7	21.5	18.4	16.1	14.3	12.9	11.7	10.7
Three point loads (quarter points)	Each kN	28.6	21.5	17.2	14.3	12.3	10.7	9.5	8.6	7.8	7.2

Notes

1. Above allowable loads may be increased by 1.11 for **wind loading only**
2. This table is provided as a guide only and assume all loads are applied at restrained nodes. All scaffolds and structures should be checked by a qualified structural engineer.
3. Maximum capacity of a point load mid way between nodes is 15kN but overall buckling of the top chord should be checked if loads are placed other than at restrained loads.
4. Shaded and italics are controlled by shear