


# **APOLLO CRADLES LTD X- BEAM CALCULATIONS**

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<b>CALCULATION SHEET</b>	Project : Apollo X-BEAM			
	Element : Brief			
	Job Number : F0021	By : anw	Date:Feb 02	
	Document No : 001	Checked : jjg	Date:Feb 02	

**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

$\rho_0 = 255 \text{ N/mm}^2$

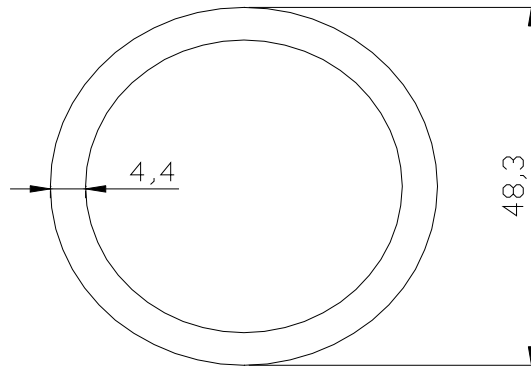
$\rho_a = 280 \text{ N/mm}^2$

$\rho_v = 155 \text{ N/mm}^2$

Loads indicated in italics and shaded are limited by shear.

CALCULATION SHEET	Project : Apollo X-BEAM			
	Element : Section Properties			
	Job Number : F0006	By : anw	Date:Feb 02	
	Document No : 001	Checked : jgg	Date:Feb 02	

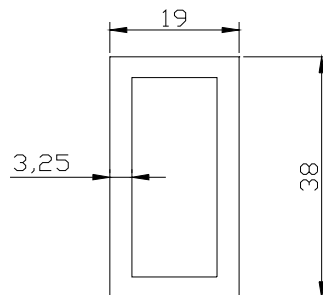
**Main boom and verticals**




Area:	606.83 mm <sup>2</sup>
Bounding box:	X: -24.15 - 24.15 mm Y: -24.15 - 24.15 mm
Moments of inertia:	X: 147654.64 mm <sup>4</sup> Y: 147654.64 mm <sup>4</sup>
Radii of gyration:	X: 15.60 mm Y: 15.60 mm
Elastic Modulus	X: 6114.06 mm <sup>3</sup> Y: 6114.06 mm <sup>3</sup>
Plastic Modulus	X: 8253.99 mm <sup>3</sup> Y: 8253.99 mm <sup>3</sup>

**Diagonals**

Loads in



Area:	328.25 mm <sup>2</sup>
Bounding box:	X: -9.5 -- 9.5 mm Y: -19.00 -- 19.00 mm
Moments of inertia:	X: 54322.46 mm <sup>4</sup> Y: 16593.21 mm <sup>4</sup>
Radii of gyration:	X: 12.86 mm Y: 7.11 mm
Elastic Modulus	X: 2859.08 mm <sup>3</sup> Y: 1746.65 mm <sup>3</sup>
Plastic Modulus	X: 3758.22 mm <sup>3</sup> Y: 2199.03 mm <sup>3</sup>

CALCULATION SHEET	Project : Apollo X-BEAM			
	Element : Main boom			
	Job Number : F0006	By : anw	Date:Feb 02	
	Document No : 001	Checked : jfg	Date:Feb 02	

### Classification

4.3.1

$$\begin{aligned}\beta &= 3*((D/t)^{0.5}) \\ &= 3*((48.3-4.4)/4.4)^{0.5} \\ &= 9.48\end{aligned}$$

$$\begin{aligned}\varepsilon &= (250/p_0)^{0.5} \\ &= (250/255)^{0.5} \\ &= 0.99\end{aligned}$$

$$\begin{aligned}\beta_1 &= 15\varepsilon \\ &= 15*0.99 \\ &= 14.85 \\ &> 9.48\end{aligned}$$

Section is compact

### Bending capacity 4.5.2.2

$$\begin{aligned}M_{rs} &= p_0 S_n / \gamma_m & p_0 &= 255 \text{ N/mm}^2 \\ & & S_n &= 8.25 \text{ cm}^3 \\ & & \gamma_m &= 1.2 \\ &= 255 * 8.25 / 1200 \\ &= \mathbf{1.74 \text{ kNm}}\end{aligned}$$

### Shear 4.5.3.2

$$\begin{aligned}V_{rs} &= p_v A_v / \gamma_m & p_v &= 155 \text{ N/mm}^2 \\ & & A_v &= 0.6A \\ & & &= 0.6 * 606.83 \\ & & &= 364.1 \text{ mm}^2 \\ & & \gamma_m &= 1.2 \\ &= 155 * 364.1 / 1200 \\ &= \mathbf{47.03 \text{ kN}}\end{aligned}$$

Loads indicated in italics and shaded are limited by shear.

### Lateral Torsional Buckling

No check required for CHS

### Tension


4.6  
for General Tension

$$\begin{aligned}P_{rs} &= p_0 A / \gamma_m & p_0 &= 255 \text{ N/mm}^2 \\ & & A &= 606.83 \text{ mm}^2 \\ & & \gamma_m &= 1.3 \\ &= 255 * 606.83 / 1300 \\ &= \mathbf{119.03 \text{ kN}}\end{aligned}$$

For local at splice

$$\begin{aligned}P_{rs} &= p_a A_n / \gamma_m & p_a &= 280 \text{ N/mm}^2 \\ & & A_n &= A - 2dt \\ & & &= 606.83 - 2 * 14 * 4.4 \\ & & &= 483.63 \text{ mm}^2 \\ & & \gamma_m &= 1.3 \\ &= 280 * 483.63 / 1300 \\ &= \mathbf{104.17 \text{ kN}}\end{aligned}$$

### Compression

CALCULATION SHEET	Project : Apollo X-BEAM			 ALAN WHITE DESIGN
	Element : Main boom			
	Job Number : F0006	By : anw	Date:Feb 02	
	Document No : 001	Checked : jjg	Date:Feb 02	

4.7

$$Pr = \quad psA/\gamma m$$

**for 1m bracing**

$$L = \quad 950.00 \text{ m}$$

$$r = \quad 15.6 \text{ mm}$$

$$\lambda = KL/r \quad K = 0.7$$

$$0.7 * 950 / 15.6$$

$$42.63$$

Fig 4.10b gives


$$ps = \quad 184.00 \text{ N/mm}^2$$

$$A = 606.83 \text{ mm}^2$$

$$\gamma m = 1.3$$

$$Pr = 184 * 606.83 / 1300$$

$$= \quad \mathbf{85.89 \text{ kN}}$$

CALCULATION SHEET	Project : Apollo X-BEAM			
	Element : Diagonal			
	Job Number : F0006	By : anw	Date:Feb 02	
	Document No : 001	Checked : jgg	Date:Feb 02	

**Classification**

4.3.1

$$\begin{aligned} \beta &= 3*((D/t)^{0.5}) \\ &= 3*((38-3.25)/3.25)^{0.5} \\ &= 9.81 \end{aligned}$$

$$\begin{aligned} \epsilon &= (250/p_0)^{0.5} \\ &= (250/255)^{0.5} \\ &= 0.99 \end{aligned}$$

$$\begin{aligned} \beta_1 &= 15\epsilon \\ &= 15*0.99 \\ &= 14.85 \\ &> 9.81 \end{aligned}$$

**Section is compact**

**Bending capacity** 4.5.2.2

$$\begin{aligned} M_{rs} &= p_0 S_n / \gamma_m & p_0 &= 255 \text{ N/mm}^2 \\ & & S_n &= 3.76 \text{ cm}^3 \\ & & \gamma_m &= 1.3 \\ &= 255 * 3.76 / 1300 \\ &= \mathbf{0.74 \text{ kNm}} \end{aligned}$$

**Shear** 4.5.3.2

$$\begin{aligned} V_{rs} &= p_v A_v / \gamma_m & p_v &= 155 \text{ N/mm}^2 \\ & & A_v &= 0.8 N D t \\ & & &= 0.8 * 2 * 38 * 3.25 \\ & & &= 197.6 \text{ mm}^2 \\ & & \gamma_m &= 1.3 \\ &= 155 * 197.6 / 1300 \\ &= \mathbf{23.56 \text{ kN}} \end{aligned}$$

Loads indicated in italics and shaded are limited by shear.

**Lateral Torsional Buckling**

$$\text{overall length } L = \frac{\text{SQRT}(652^2 + 425^2)}{778.29}$$

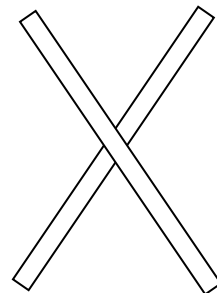
length to brace point is L/2

$$\begin{aligned} L_e &= 0.85 * 778.29 / 2 \\ &= 330.77 \end{aligned}$$

$$\begin{aligned} \lambda &= L_e / r_y \\ &= 330.77 / 7.11 \\ &= 47 \end{aligned}$$


$$p_s = 220 \text{ N/mm}^2$$

$$\begin{aligned} M_{rx} &= p_s S / \gamma_m & S &= 3.76 \text{ cm}^3 \\ & & \gamma_m &= 1.2 \\ &= 220 * 3.76 / 1200 \\ &= \mathbf{0.69 \text{ kNm}} \end{aligned}$$



**Tension**

4.6

<b>CALCULATION SHEET</b>	Project : Apollo X-BEAM			
	Element : Diagonal			
	Job Number : F0006	By : anw	Date: Feb 02	
	Document No : 001	Checked : jjg	Date: Feb 02	

for General Tension only ( no local holes)

$$\begin{aligned}
 Pr &= p_o A / \gamma_m & p_o &= 255 \text{ N/mm}^2 \\
 & & A &= 328.3 \text{ mm}^2 \\
 & & \gamma_m &= 1.2 \\
 &= 255 * 328.3 / 1200 \\
 &= \mathbf{69.76 \text{ kN}}
 \end{aligned}$$

### Compression

4.7

$$\begin{aligned}
 Pr &= p_s A / \gamma_m \\
 L &= 0.338 \text{ m} \\
 r &= 7.11 \text{ mm} \\
 \lambda &= KL / r & K &= 0.7 \\
 &= 0.7 * 338 / 7.11 \\
 &= 33.28
 \end{aligned}$$


Fig 4.10b gives

$$\begin{aligned}
 ps &= 182.00 \text{ N/mm}^2 & A &= 328.3 \text{ mm}^2 \\
 & & \gamma_m &= 1.2 \\
 Pr &= 182 * 328.3 / 1200 \\
 &= \mathbf{49.79 \text{ kN}}
 \end{aligned}$$

for local squashing

$$\begin{aligned}
 Pr &= p_a A_e / \gamma_m & p_a &= 280 \text{ N/mm}^2 \\
 & & A_e &= 164.2 \text{ mm}^2 \\
 & & \gamma_m &= 1.2 \\
 &= 280 * 164.2 / 1200 \\
 &= \mathbf{38.31 \text{ kN}}
 \end{aligned}$$

Use local squashing value

<b>CALCULATION SHEET</b>	Project : Apollo X-BEAM			
	Element : Diagonal			
	Job Number : F0006	By : anw	Date:Feb 02	
	Document No : 001	Checked : jgg	Date:Feb 02	

**Tension**

4.6

for General Tension only ( no local holes)


$$\begin{aligned}
 \text{Prs} &= \rho_o A / \gamma_m & \rho_o &= 255 \text{N/mm}^2 \\
 & & A &= 328.3 \text{mm}^2 \\
 & & \gamma_m &= 1.3 \\
 &= 255 * 328.3 / 1300 \\
 &= \mathbf{64.40 \text{ kN}}
 \end{aligned}$$

for local softening

$$\begin{aligned}
 \text{Prs} &= \rho_a A_e / \gamma_m & \rho_a &= 280 \text{N/mm}^2 \\
 & & A_e &= 164.2 \text{mm}^2 \\
 & & \gamma_m &= 1.2 \\
 &= 280 * 164.2 / 1200 \\
 &= \mathbf{38.31 \text{ kN}}
 \end{aligned}$$

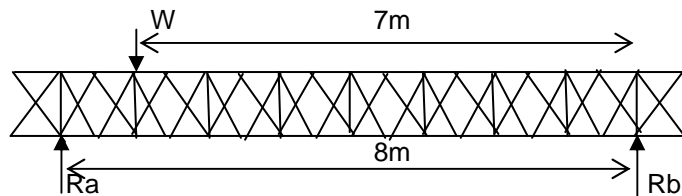
**Loads indicated in italics and shaded are limited by shear.**



<b>CALCULATION SHEET</b>	Project : Apollo X-BEAM			
	Element : Load Case 2- 1m bracing			
	Job Number : F0006	By : anw	Date:Feb 02	
	Document No : 001	Checked : jjg	Date:Feb 02	

Load Case 2      Load at end      (note Load case 1 was not used for analysis - 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
				<b>Factor</b>	<b>5.18</b>



Max shear Ra=  $W \cdot 7/8$

Loads indicated in italics and shaded are limited by shear.  
 so for ultimate condition

$W = 1.33 \cdot 10$   
**13.30 kN**

apply factor from above

$W_f = 13.3 \cdot 5.18$   
**69.05 kN**


so reaction at A is max shear

Ultimate Ra=  $W_f \cdot 7/8$   
**Ultimate shear= 60.42 kN**

and for allowable value

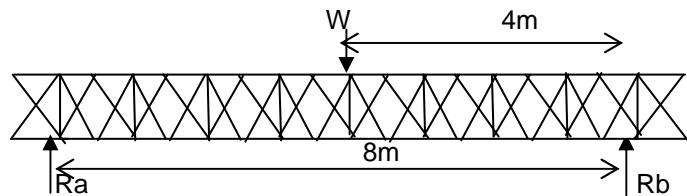
allowable Shear=  $60.42 / 1.33$   
 = **45.43 kN**

<b>Shear values</b>	<b>Ultimate</b>	<b>60.42 kN</b>
	<b>Allowable</b>	<b>45.43 kN</b>

<b>CALCULATION SHEET</b>	Project : Apollo X-BEAM			
	Element : Load Case 3- 1m bracing			
	Job Number : F0006	By : anw	Date:Feb 02	
	Document No : 001	Checked : jgg	Date:Feb 02	

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
				<b>Factor</b>	<b>2.17</b>



Max Moment=  $ML/4$

Loads indicated in italics and shaded are limited by shear.  
 so for ultimate condition

$W = 1.33 \cdot 10$   
**13.30 kN**

apply factor from above

$W_f = 13.3 \cdot 2.17$   
 28.93


so maximum moment is as above

Ultimate  $M_u = W_f \cdot 8/4$   
 $28.93 \cdot 8/4$   
**57.86 kN**

and for allowable value

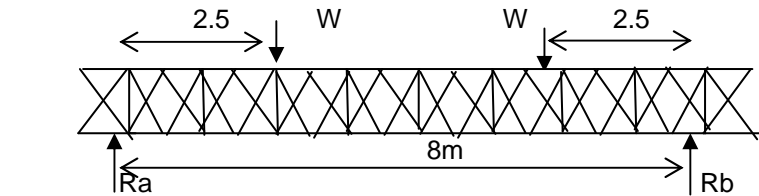
allowable max moment=  $57.86/1.33$   
 = **43.50 kN**

<b>Moment values</b>	<b>Ultimate</b>	<b>57.86 kN</b>
	<b>Allowable</b>	<b>43.50 kN</b>

CALCULATION SHEET	Project : Apollo X-BEAM			
	Element : Load Case 4- 1m bracing			
	Job Number : F0006	By : anw	Date:Feb 02	
	Document No : 001	Checked : jgg	Date:Feb 02	

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
				<b>Factor</b>	<b>1.71</b>



Loads indicated in i Max Moment= 2.5W

so for ultimate condition

$$W = \frac{1.33 \cdot 10}{1.33} = 13.30 \text{ kN}$$

apply factor from above

$$W_f = 13.3 \cdot 1.71 = 22.79$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= W_f \cdot 2.5 \\ &= 22.79 \cdot 2.5 \\ &= 56.99 \text{ kN} \end{aligned}$$

and for allowable value

$$\begin{aligned} \text{allowable max moment} &= 56.99 / 1.33 \\ &= 42.85 \text{ kN} \end{aligned}$$

Moment values	Ultimate	56.99 kN
	Allowable	42.85 kN

CALCULATION SHEET	Project : Apollo X-BEAM			 ALAN WHITE DESIGN
	Element : Summary			
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### Test Results

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

<b>Allowable moment</b>	<b>42.9 kNm</b>
<b>Ultimate moment</b>	<b>57.0 kNm</b>

### Selected results

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

Max moment on the beam is

<b>Allowable moment</b>	<b>42.9 kNm</b>
<b>Ultimate moment</b>	<b>57.0 kNm</b>

and Maximum Shear is

<b>Allowable shear</b>	<b>45.4 kN</b>
<b>Ultimate shear</b>	<b>60.4 kN</b>

Loads indicated in italics and shaded are limited by shear.

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

Type of Load		Clear span (m)									
		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. Loads indicated in italics and shaded are limited by shear.