



**APOLLO CRADLES LTD
X-BEAM CALCULATION TO BS EN 1999-1-1
DESIGN CHECK CALCULATIONS**

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OCT 2014

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DESIGN REPORT

TABLE OF CONTENTS

TABLE OF CONTENTS	1
INTRODUCTION	2
EXECUTIVE SUMMARY	2
DESIGN PHILOSOPHY	2
ANALYSIS.....	3
CONCLUSIONS	3
CALCULATIONS.....	4



INTRODUCTION

Alan White Design Ltd has been commissioned by APOLLO CRADLES Ltd as consultants to provide design and detailed calculations to allow the safe use and manufacture of the Aluminium X-beam as per BS EN 1999-1-1.

The report investigates various lengths of X-Beams under various loading conditions from which the minimum values are then used to extrapolate an easy to read graph and table for allowable working loads for the various loading methods.

This report is intended to provide the information necessary for scrutinising verification authorities to discern the relevant structural engineering aspects for this aluminium structure.

This report provides the details of the loading methods and structural capacity of all members and their performance in the structure. The results for each loading method for a 3m, 6m, 9m, 12m, 15m and 18m X-beams are given and summarised. The overall recommended allowable values are then tabulated.

EXECUTIVE SUMMARY

The X-Beams can be used in a variety of methods and a variety of locations and it is the responsibility of the contractor to ensure that the recommended results from this report are a suitable assumption for their usage of the system, all based upon restraint to top & bottom booms at 1.0m c/c.

DESIGN PHILOSOPHY

The X-Beam is made up a top and bottom boom both using Alu scaffold tubes, with Alu scaffold tubes verticals at 1m spacing's. These vertical are then braced using Alu rectangular hollow sections in a 500mm wide X shape, with two of these brace systems between each vertical.



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ANALYSIS

Detailed structural analysis has been completed using STRAP structural analysis software. This model was subjected to the worst possible loading conditions to determine the structures expected maximum stresses. This model has been used to identify the member forces and deflections in the structure. Hand calculations have been incorporated to check element capacities and the maximum stresses were compared to the allowable stresses to verify the safety of the structure.


CONCLUSIONS

The recommended allowable loadings for the X-Beam according to BS EN 1999-1 are contained at the end of the report.



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CALCULATIONS

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	Brief			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked :anw	Date: Oct 14	

Brief The brief is to prepare calculated values for the capacity of the Apollo 750mm deep X-BEAM to BS EN 1999-1-1.

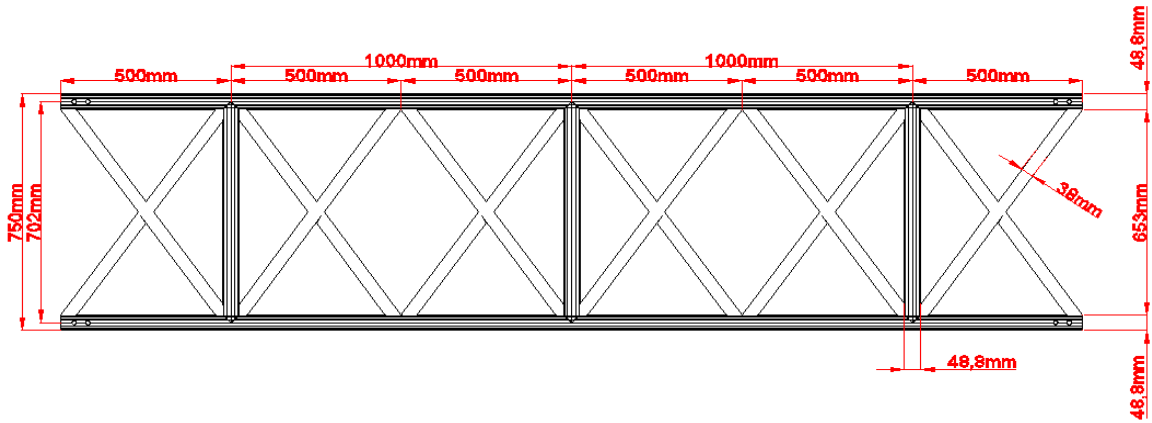
The beams are manufactured from tube extrusions in aluminium alloy 6082 T6.

Alloy The alloy used is 6082 T6:

$$f_o = 250 \text{ N/mm}^2$$

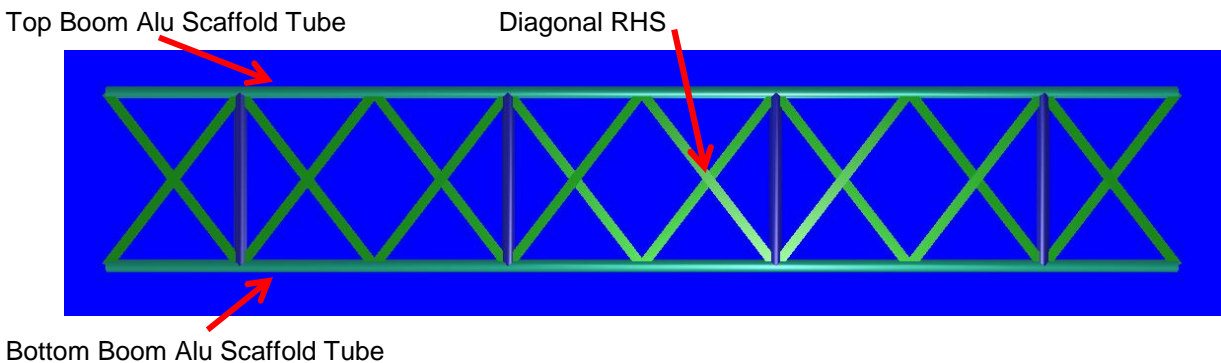
$$f_u = 290 \text{ N/mm}^2$$


Layout The geometry of the beam is shown in the drawing below:



Design Eurocode 9: Design of Aluminium structures EN 1999-1-1
Alloy used is 6082 T6 throughout

STRAP Model The structure was analysed in STRAP structural analysis program.
(3m X-Beam shown below, larger spans are scaled versions of below)



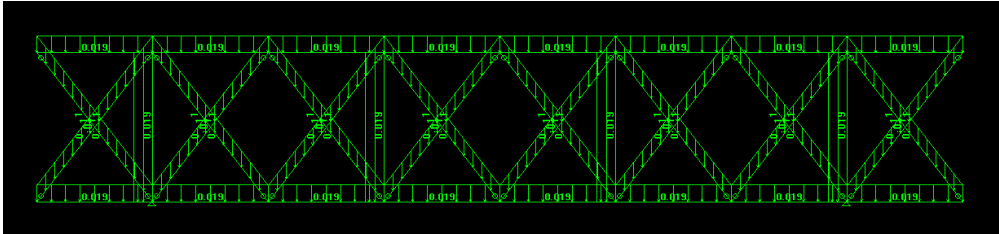
CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
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	Job Number :	R0076	By : eas	Date: Oct 14	
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Load Cases

Images are shown of the 3m beam, loading for larger spans is applied using the same methodology.

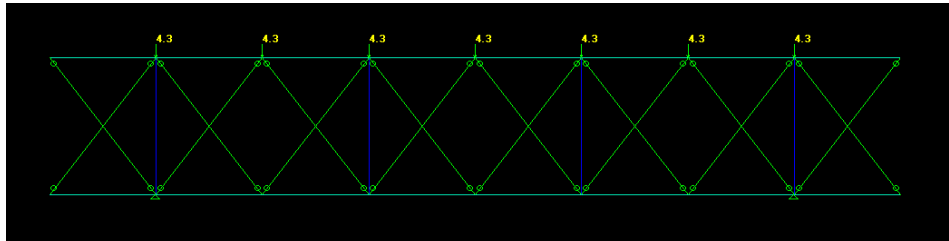
Load Case 1

Self Weight
Self weight of all members and rails factored by 1.15 to account for all connections



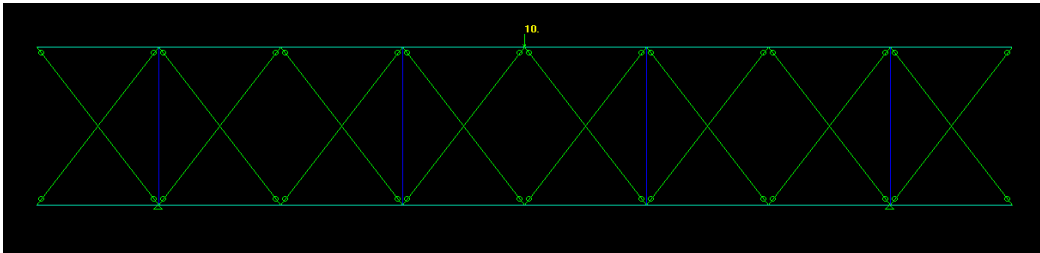
Load Case 2

UDL
10kN/m Load Applied to top boom over full length of the X-Beam at node points



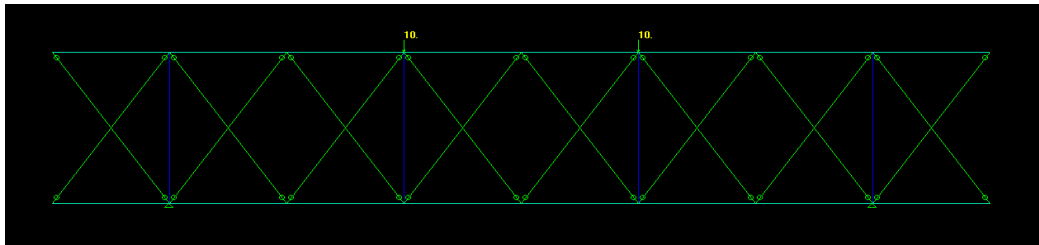
Load Case 3


Central Point Load
10kN Point Load Applied to Centre of Top Boom of the X-Beam



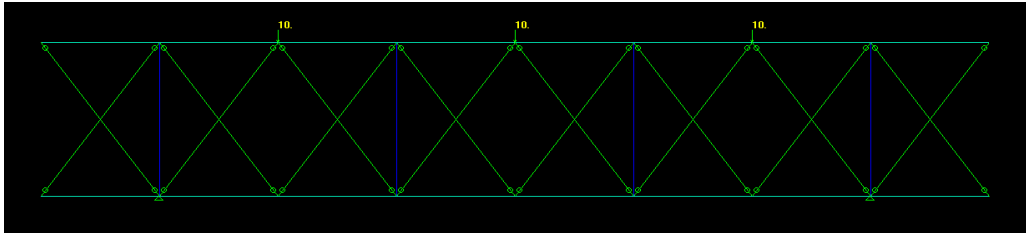
Load Case 4

Two Point Loads
2No 10kN point loads applied at third points along the top boom of the X-Beam.

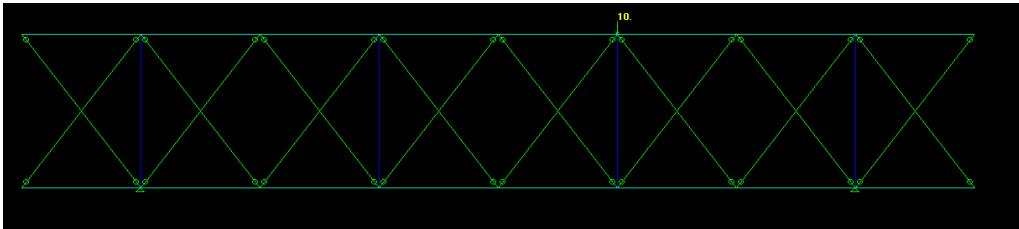


CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
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	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked :anw	Date: Oct 14	

Load Case 5 Three Point Loads
3No 10kN Point Loads applied at quarter points along the X-Beam



Load Case 6 End Shear
10kN Point Load applied 1m from support




Load Combinations

Combination Number	Combination Description	Load Cases
1	UDL	1+2
2	Central Point Load	1+3
3	Two Point Loads	1+4
4	Three Point Loads	1+5
5	End Shear	1+6

Above Combinations were checked for the following design factors:

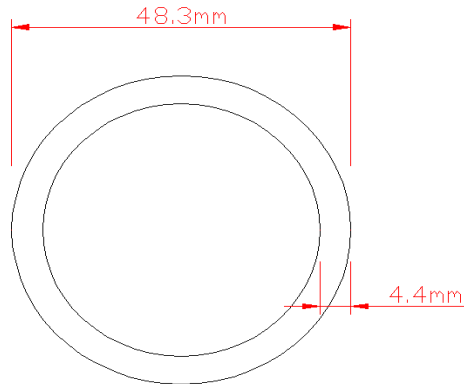
$$\gamma_D = 1.25$$

$$\gamma_L = 1.50$$

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	Main Boom Capacity			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked :anw	Date: Oct 14	

CHS Boom Layout

Boom 48.3 x 4.4 CHS



Section Properties

$$\begin{aligned}
A &= 607 \text{ mm}^2 \\
I &= 147654 \text{ mm}^4 \\
W_{el} &= 6114 \text{ mm}^3 \\
W_{pl} &= 8254 \text{ mm}^3 \\
r_y &= 15.6 \text{ mm}
\end{aligned}$$

for slenderness

$$\begin{aligned}
\beta &= b/t & b &= 48.3 \\
&= 10.98 & t &= 4.4
\end{aligned}$$

$$\begin{aligned}
\varepsilon &= \text{sqrt}(250/f_o) & f_o &= 250\text{N/mm}^2 \\
&= 1.00
\end{aligned}$$

Class A, without welds, Internal parts

$$\begin{aligned}
\beta_1 &= 11\varepsilon \\
&= 11*1.0 \\
&= 11.00 \\
&> 10.98
\end{aligned}$$

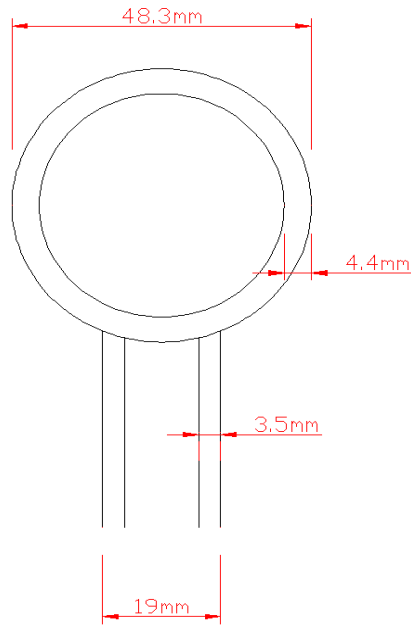
Section is class 1

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	Main Boom Capacity		
	Job Number :	R0076	By : eas	Date: Oct 14
	Document No :	001B	Checked :anw	Date: Oct 14



Boom 48.3 x 4.4 CHS HAZ

There is a HAZ at welded joint to the diagonal brace



$$t_{boom} = 4.40\text{mm}$$


$$t_{diagonal} = 3.5\text{mm}$$

$$t_{average} = 3.95\text{mm}$$

All welds are TIG.
As per EN 1999-1-1 6.1.6.3

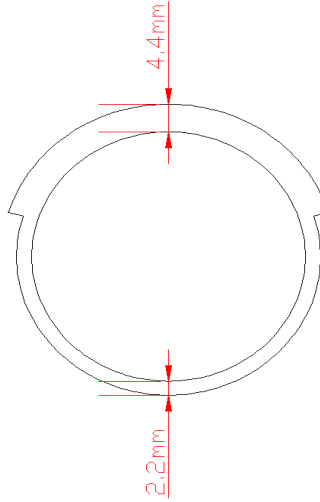
$$b_{haz} = 30\text{mm}$$

Therefore HAZ extends 30mm from intersection of welded materials

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HAZ Section Layout

Take section shown as non-HAZ.



HAZ Section Properties

A=	418 mm ²
I=	92785 mm ⁴
W _{el} =	3398 mm ³
W _{pl} =	4587 mm ³
r _y =	14.7 mm

Truss Boom Moment Capacity

(6.2.5.1)

$$M_{c,Rd} = \alpha W_{el} f_o / \gamma_{M1}$$

$\alpha =$	W_{pl}/W_{el} (Table 6.4)
$=$	1.35
$W_{el} =$	3.40 cm ³
$f_o =$	250 N/mm ²
$\gamma_{M1} =$	1.1 (6.1.3)

$$= 1.35 * 3.40 * 250 / 1100$$

$$M_{c,Rd} = 1.04 \text{ kNm}$$

Truss Boom Shear Capacity


(6.2.6)

$$V_{Rd} = A_v f_o / \sqrt{3} \gamma_{M1}$$

$A_v =$	0.6A
$A_v =$	0.6 * 418
$A_v =$	250.80 mm ²
$\gamma_{M1} =$	1.1
$f_o =$	250 N/mm ²

$$= 250.80 * 250 / (\text{SQRT}(3) * 1100)$$

$$V_{Rd} = 32.91 \text{ kN}$$

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	Main Boom Capacity			
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Truss Boom Axial Comp Capacity @ 1000mm (effective length of beam between restraints)

$$N_{b,Rd} = k \times A_{eff} f_o / \gamma_{M1} \quad (6.3.1.1)$$

$$N_{cr} = \pi^2 EI / k^2 L^2 \quad (\text{Appendix I.3})$$

$$E = 70,000 \text{ N/mm}^2$$

$$I = 147,654 \text{ mm}^4$$

$$k = 0.50 \text{ (Table I.2)}$$

$$L = 1,000 \text{ mm}$$

$$N_{cr} = ((\pi)^2 * 70000 * 147654) / ((0.5^2) * (1000^2))$$

$$= 408,040.24 \text{ N}$$

$$\lambda = \sqrt{A_{eff} f_o / N_{cr}} \quad (6.3.1.2)$$

$$= 0.61 \quad A_{eff} = 607 \text{ mm}^2$$

$$X = 1 / \Phi + \sqrt{\Phi^2 - \lambda^2}$$

$$\Phi = 0.5(1 + \alpha(\lambda - \lambda_o) + \lambda^2)$$

$$\alpha = 0.20 \text{ Table 6.6}$$

$$\lambda_o = 0.10 \text{ Table 6.6}$$

$$\Phi = 0.74$$

$$X = 0.87$$

$$k = 1 - (1 - (A_1/A) 10^{-\lambda} - (0.005 + 0.1(A_1/A))) \lambda^{1.3(1-\lambda)}$$

$$A_1 = A - A_{HAZ}(1 - p_{o,HAZ})$$

$$= 607 - 189 * (1 - 0.5)$$


$$= 512.50 \text{ mm}^2$$

$$k = 0.857$$

$$N_{b,Rd} = k \times A_{eff} f_o / \gamma_{M1}$$

$$N_{b,Rd} = 0.857 * 0.87 * 607 * 250 / 1100$$

$$= 102.86 \text{ kN}$$

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	Main Boom Capacity			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked :anw	Date: Oct 14	

Truss Boom Axial Tension Capacity

(6.2.3)

1. General yielding


$$\begin{aligned}
N_{o,Rd} &= A_g f_o / \gamma_{M1} \\
&= 607 * 250 / 1100 \\
&= 137.95 \text{ kN}
\end{aligned}$$

$$\begin{aligned}
f_o &= 250 \text{ N/mm}^2 \\
A_g &= 607 \text{ mm}^2 \\
\gamma_{M1} &= 1.1
\end{aligned}$$

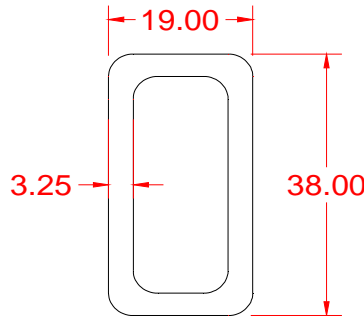
2. Local failure

$$\begin{aligned}
N_{u,Rd} &= A_{net} f_u / \gamma_{M2} \\
&= 388.5 * 290 / 1250 \\
&= 90.13 \text{ kN}
\end{aligned}$$

$$\begin{aligned}
f_u &= 290 \text{ N/mm}^2 \\
A_{net} &= \rho_{u,haz} * A \\
&= 0.64 * 607 \text{ mm}^2 \\
&= 388.5 \text{ mm}^2 \\
\gamma_{M1} &= 1.25
\end{aligned}$$

CALCULATION SHEET	Project : Apollo Box X-beam to Eurocode			 ALAN WHITE DESIGN
	Element : Diagonal Member Capacity			
	Job Number : R0076	By : eas	Date: Oct 14	
	Document No : 001B	Checked :anw	Date: Oct 14	

RHS-Oval Diagonal Member
Diagonal 38 x 19 x 3.25mm Oval



Section Properties

A=	328 mm ²
I=	53341 mm ⁴
W _{el} =	2807 mm ³
W _{pl} =	3729 mm ³
r _y =	7.0 mm

for slenderness

β=	b/t	b= 38-2*3.25
=	9.69	= 31.50
		t = 3.25
ε=	sqrt(250/f _o)	f _o = 250N/mm ²
=	1.00	

Class A, without welds, Internal parts

β ₁ =	11ε
=	11*1.0
=	11.00
>	9.69

Section is class 1

Diagonal Axial Comp Capacity @ 400mm (effective length of beam)

$$N_{b,Rd} = k \times A_{eff} f_o / \gamma_{M1} \quad (6.3.1.1)$$

$$N_{cr} = \pi^2 EI / k^2 L^2 \quad (\text{Appendix I.3})$$


E =	70,000 N/mm ²
I =	53,341 mm ⁴
k =	0.50
L =	400 mm

$$N_{cr} = ((\pi)^2 * 70000 * 53341) / ((0.5^2) * (400^2))$$

$$= 921,295.49 \text{ N}$$

$$\lambda = \sqrt{A_{eff} f_o / N_{cr}} \quad (6.3.1.2)$$

$$= 0.30 \quad A_{eff} = 328 \text{ mm}^2$$

CALCULATION SHEET	Project : Apollo Box X-beam to Eurocode			 ALAN WHITE DESIGN
	Element : Diagonal Member Capacity			
	Job Number : R0076	By : eas	Date: Oct 14	
	Document No : 001B	Checked : anw	Date: Oct 14	

$$X = 1 / \Phi + \sqrt{\Phi^2 - \lambda^2}$$

$$\Phi = 0.5(1 + \alpha(\lambda - \lambda_0) + \lambda^2)$$

$$\alpha = 0.20 \text{ Table 6.6}$$

$$\lambda_0 = 0.10 \text{ Table 6.6}$$

$$\Phi = 0.56$$

$$X = 0.89$$

$$k = 1 - (1 - (A_1/A)10^{-\lambda} - (0.005 + 0.1(A_1/A)))\lambda^{1.3(1-\lambda)}$$

$$\begin{aligned} A_1 &= A - A_{HAZ}(1 - p_{o,HAZ}) \\ &= 328 - 126.4 * (1 - 0.5) \\ &= 264.80 \text{ mm}^2 \end{aligned}$$

$$k = 0.946$$

$$\begin{aligned} N_{b,Rd} &= 0.946 * 0.89 * 328 * 250 / 1100 \\ &= 62.76 \text{ kN} \end{aligned}$$

Diagonal Axial Tension Capacity

(6.2.3)

1. General yielding

$$\begin{aligned} N_{o,Rd} &= A_g f_o / \gamma_{M1} \\ &= 328 * 250 / 1100 \\ &= 79.55 \text{ kN} \end{aligned}$$

$$f_o = 250 \text{ N/mm}^2$$

$$A_g = 328 \text{ mm}^2$$

$$\gamma_{M1} = 1.1$$

2. Local failure

$$\begin{aligned} N_{u,Rd} &= A_{net} f_u / \gamma_{M2} \\ &= 209.9 * 290 / 1250 \\ &= 48.70 \text{ kN} \end{aligned}$$


$$f_u = 290 \text{ N/mm}^2$$

$$A_{net} = \rho_{u,haz} * A$$

$$= 0.64 * 328 \text{ mm}^2$$

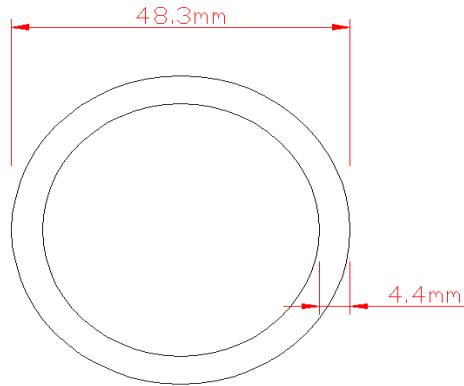
$$= 209.9 \text{ mm}^2$$

$$\gamma_{M2} = 1.25$$

CALCULATION SHEET	Project :	Apollo Box X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	Vertical capacity			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked :anw	Date: Oct 14	

Vertical 48.3 x 4.4mm CHS

Vertical CHS Layout



Section Properties

A=	607 mm ²
I=	147654 mm ⁴
W _{el} =	6114 mm ³
W _{pl} =	8254 mm ³
r _y =	15.6 mm

for slenderness


β =	b/t	b= 48.3
=	10.98	t = 4.4

ϵ =	sqrt(250/f _o)	f _o = 250N/mm ²
=	1.00	

Class A, without welds, Internal parts

β_1 =	11 ϵ
=	11*1.0
=	11.00
>	10.98

Section is class 1

CALCULATION SHEET	Project :	Apollo Box X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	Vertical capacity			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked :anw	Date: Oct 14	

Vertical CHS Moment Capacity

(6.2.5.1)

$$M_{c,Rd} = \alpha W_{el} f_o / \gamma_{M1}$$

$$\alpha = W_{pl}/W_{el} \text{ (Table 6.4)}$$

$$= 1.35$$

$$W_{el} = 6.11 \text{ cm}^3$$

$$f_o = 250 \text{ N/mm}^2$$

$$\gamma_{M1} = 1.1 \text{ (6.1.3)}$$

$$= 1.35 * 6.11 * 250 / 1100$$

$$M_{c,Rd} = 1.87 \text{ kNm}$$

$$M_{u,Rd} = W_{net} f_u / \gamma_{M2}$$

$$W_{net} = W_{el} * \rho_{u, haz}$$

$$= 6.11 * 0.64$$

$$= 3.91 \text{ cm}^3$$

$$f_u = 290 \text{ N/mm}^2$$

$$\gamma_{M2} = 1.25 \text{ (6.1.3)}$$

$$= 3.91 * 290 / 1250$$

$$M_{u,Rd} = 0.91 \text{ kNm}$$

$$M_{Rd,x} = 0.91 \text{ kNm} \quad \text{lesser value of } M_{c,Rd} / M_{u,Rd}$$

Vertical CHS Shear Capacity

(6.2.6)

$$V_{Rd} = A_v f_o / \sqrt{3} \gamma_{M1}$$

$$A_v = 0.6A$$

$$= 0.6 * 607$$

$$= 364.20 \text{ mm}^2$$

$$\gamma_{M1} = 1.1$$

$$f_o = 250 \text{ N/mm}^2$$

$$= 364.20 * 250 / (\text{SQRT}(3) * 1100)$$

$$V_{Rd} = 47.79 \text{ kN}$$

Vertical CHS Axial Comp Capacity @ 750mm (effective length of beam)

$$N_{b,Rd} = k \times A_{eff} f_o / \gamma_{M1} \quad (6.3.1.1)$$

$$k = \omega_x$$

$$\omega_x = \frac{\rho_{u, haz} f_u / \gamma_{M2}}{f_o / \gamma_{M1}}$$

$$= (0.64 * 290 / 1.25) / (250 / 1.1)$$

$$= 0.65$$

$$k = 0.65$$

$$N_{cr} = \pi^2 EI / k^2 L^2 \quad \text{(Appendix I.3)}$$

$$E = 70,000 \text{ N/mm}^2$$


$$I = 147,654 \text{ mm}^4$$

$$k = 0.50$$

$$L = 750 \text{ mm}$$

$$N_{cr} = ((\text{PI})^2 * 70000 * 147654) / ((0.5^2) * (750^2))$$

$$= 725,404.87 \text{ N}$$

CALCULATION SHEET	Project :	Apollo Box X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	Vertical capacity			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked :anw	Date: Oct 14	

$$\lambda = \sqrt{A_{\text{eff}} f_o / N_{\text{cr}}} \quad (6.3.1.2)$$

$$= 0.46 \quad A_{\text{eff}} = 607 \text{ mm}^2$$

$$X = 1 / (\Phi + \sqrt{\Phi^2 - \lambda^2})$$

$$\Phi = 0.5(1 + \alpha(\lambda - \lambda_o) + \lambda^2)$$

$$\alpha = 0.20 \text{ Table 6.6}$$

$$\lambda_o = 0.10 \text{ Table 6.6}$$

$$\Phi = 0.64$$

$$X = 0.79$$

$$k = 1 - (1 - (A_1/A)10^{-\lambda} - (0.005 + 0.1(A_1/A)))\lambda^{1.3(1-\lambda)}$$

$$A_1 = A - A_{\text{HAZ}}(1 - p_{o,\text{HAZ}})$$

$$= 607 - 303 * (1 - 0.5)$$

$$= 455.50 \text{ mm}^2$$

$$k = 0.985$$

$$N_{b,\text{Rd}} = 0.985 * 0.79 * 607 * 250 / 1100$$

$$= 107.35 \text{ kN}$$

Vertical CHS Axial Tension Capacity

(6.2.3)

1. General yielding

$$N_{o,\text{Rd}} = A_g f_o / \gamma_{M1}$$

$$f_o = 250 \text{ N/mm}^2$$

$$A_g = 607 \text{ mm}^2$$

$$\gamma_{M1} = 1.1$$

$$= 607 * 250 / 1100$$

$$= 137.95 \text{ kN}$$

2. Local failure

$$N_{u,\text{Rd}} = A_{\text{net}} f_u / \gamma_{M2}$$

$$f_u = 290 \text{ N/mm}^2$$

$$A_{\text{net}} = A * \rho_{u,\text{haz}}$$

$$= 607 * 0.64$$

$$= 388.5 \text{ mm}^2$$

$$\gamma_{M1} = 1.25$$

$$= 388.5 * 290 / 1250$$


$$= 90.13 \text{ kN}$$

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	3m X-Beam Results		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



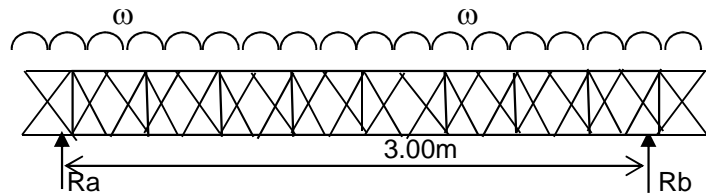
ALAN WHITE DESIGN

3m X-Beam Results

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	3m X-Beam Load Combination 1			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb.1 UDL load 10kN/m applied along beam

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.07	15.12
	Shear	V_{Rd}	32.91	0.21	155.97
	Tension	$N_{o,Rd}$	90.13	6.12	14.73
	Compression	$N_{b,Rd}$	102.86	18.45	5.57
	Deflection	d	30	0.96	31.25
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	4.33
Vertical	Moment	$M_{c,Rd}$	0.91	0.03	32.40
	Shear	V_{Rd}	47.79	0.08	604.92
	Tension	$N_{o,Rd}$	90.13	0.00	90132.00
	Compression	$N_{b,Rd}$	107.35	12.03	8.93
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	7.37
Diagonal	Tension	$N_{o,Rd}$	48.70	6.84	7.12
	Compression	$N_{b,Rd}$	62.76	12.75	4.92
Factor					4.33



$$\text{Max Moment} = \frac{ML^2}{8}$$

so for ultimate condition

$$W = \frac{15 \times 10}{3} = 15.00 \text{ kN}$$

apply factor from above

$$W_f = 15 \times 4.33 = 64.95 \text{ kN}$$

so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= \frac{W_f \times 3^2}{8} \\ &= \frac{64.95 \times 3^2}{8} \\ &= 73.07 \text{ kNm} \end{aligned}$$

and for allowable value

$$\begin{aligned} \text{allowable max moment} &= \frac{73.07}{1.50} \\ &= 48.71 \text{ kNm} \end{aligned}$$

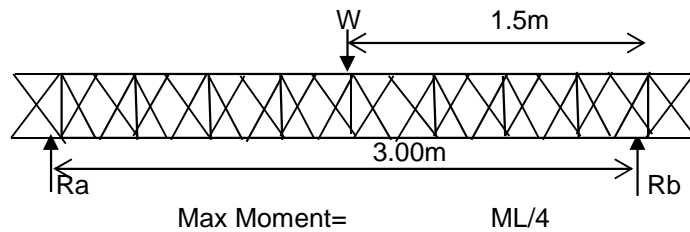
Moment values	Ultimate	73.07 kNm
	Allowable	48.71 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	3m X-Beam Load Combination 2		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



Load Comb. 2 Point load 10kN load applied at midspan of beam

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.085	12.27
	Shear	V_{Rd}	32.91	0.27	121.89
	Tension	$N_{o,Rd}$	90.13	7.08	12.73
	Compression	$N_{b,Rd}$	102.86	10.9	9.44
	Deflection	d	30	0.77	38.96
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	5.82
Vertical	Moment	$M_{c,Rd}$	0.91	0.037	24.52
	Shear	V_{Rd}	47.79	0.076	628.80
	Tension	$N_{o,Rd}$	90.13	3	30.04
	Compression	$N_{b,Rd}$	107.35	3.4	31.57
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	15.19
Diagonal	Tension	$N_{o,Rd}$	48.70	5.17	9.42
	Compression	$N_{b,Rd}$	62.76	8.9	7.05
Factor					5.82



so for ultimate condition

$$W = 1.50 \times 10 = 15.00 \text{ kN}$$

apply factor from above

$$W_f = 15 \times 5.82 = 87.30 \text{ kN}$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= W_f \times 3/4 \\ &= 87.3 \times 3/4 \\ &= 65.48 \text{ kNm} \end{aligned}$$

and for allowable value

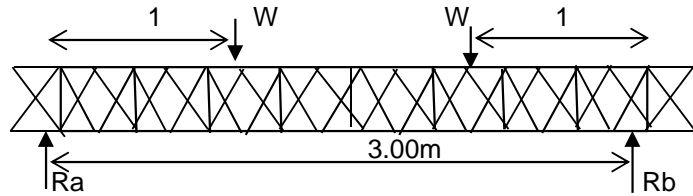
$$\begin{aligned} \text{allowable max moment} &= 65.48 / 1.50 \\ &= 43.65 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	65.48 kNm
	Allowable	43.65 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	3m X-Beam Load Combination 3			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb. 3 PL at third points 10kN load applied at each of the two third points

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.08	12.42
	Shear	V_{Rd}	32.91	0.25	134.32
	Tension	$N_{o,Rd}$	90.13	7.16	12.59
	Compression	$N_{b,Rd}$	102.86	21.36	4.82
	Deflection	d	30	1.06	28.30
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	3.70
Vertical	Moment	$M_{c,Rd}$	0.91	0.03	33.60
	Shear	V_{Rd}	47.79	0.06	746.70
	Tension	$N_{o,Rd}$	90.13	0.00	90132.00
	Compression	$N_{b,Rd}$	107.35	7.23	14.85
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	11.02
Diagonal	Tension	$N_{o,Rd}$	48.70	9.01	5.40
	Compression	$N_{b,Rd}$	62.76	9.39	6.68
Factor					3.70



Max Moment= $ML/3$

so for ultimate condition

$W = 1.50 \times 10$
15.00 kN

apply factor from above

$Wf = 15 \times 3.70$
= 55.50 kN


so maximum moment is as above

Ultimate $M_u = Wf \times 3/3$
= $(55.5 \times 3)/3$
= 55.50 kNm

and for allowable value

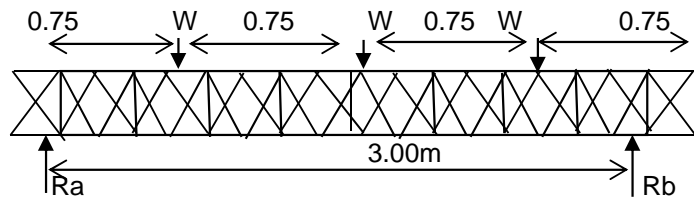
allowable max moment= $55.5/1.50$
= 37.00 kNm

Moment values	Ultimate	55.50 kNm
	Allowable	37.00 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	3m X-Beam Load Combination 4			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb. 4 PL at quarter points
10kN load applied at each of the three quarter points

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.10	10.33
	Shear	V_{Rd}	32.91	0.35	95.39
	Tension	$N_{o,Rd}$	90.13	7.11	12.68
	Compression	$N_{b,Rd}$	102.86	21.61	4.76
	Deflection	d	30	1.23	24.39
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	3.49
Vertical	Moment	$M_{c,Rd}$	0.91	0.05	18.51
	Shear	V_{Rd}	47.79	0.12	401.59
	Tension	$N_{o,Rd}$	90.13	5.98	15.08
	Compression	$N_{b,Rd}$	107.35	6.96	15.43
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	9.19
Diagonal	Tension	$N_{o,Rd}$	48.70	8.10	6.01
	Compression	$N_{b,Rd}$	62.76	19.12	3.28
Factor					3.28



Max Moment = $ML/2$

so for ultimate condition

$W = 1.50 \times 10$
15.00 kN

apply factor from above


$W_f = 15 \times 3.28$
= 49.20 kN

so maximum moment is as above

Ultimate $M_u = W_f \times L/2$
= $(49.2 \times 3/2)$
= 73.80 kNm

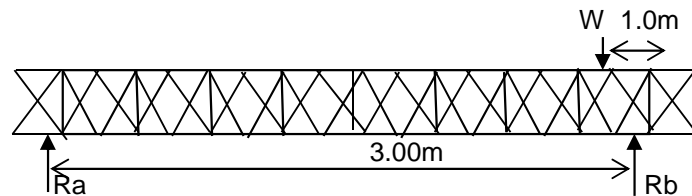
allowable max moment = $73.8/1.5$
= 49.20 kNm

Moment values	Ultimate	73.80 kNm
	Allowable	49.20 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	3m X-Beam Load Combination 5			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb. 5 End Shear 10kN load applied at a 1.0m distance from the support

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.06	17.39
	Shear	V_{Rd}	32.91	0.18	182.83
	Tension	$N_{o,Rd}$	90.13	5.66	15.92
	Compression	$N_{b,Rd}$	102.86	10.6	9.70
	Deflection	d	30	0.6	50.00
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	6.73
Vertical	Moment	$M_{c,Rd}$	0.91	0.02	50.40
	Shear	V_{Rd}	47.79	0.04	1165.58
	Tension	$N_{o,Rd}$	90.13	0.00	90132.00
	Compression	$N_{b,Rd}$	107.35	6.62	16.22
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	12.99
	Diagonal	Tension	$N_{o,Rd}$	48.70	6.2
Compression		$N_{b,Rd}$	62.76	6.34	9.90
Factor				6.73	



$$\text{Max Shear } R_b = W * 2/3$$

so for ultimate condition

$$W = 1.50 * 10 = 15.00 \text{ kN}$$

apply factor from above

$$W_f = 15 * 6.73 = 100.95 \text{ kN}$$

so maximum shear is as above

$$\begin{aligned} \text{Ultimate } Q_u &= W_f * 2/3 \\ &= (100.95 * 2) / 3 \\ &= 67.30 \text{ kN} \end{aligned}$$

and for allowable value

$$\begin{aligned} \text{allowable max shear} &= 67.30 / 1.50 \\ &= 44.87 \text{ kN} \end{aligned}$$

Shear values	Ultimate	67.30 kN
	Allowable	44.87 kN

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	3m X-Beam Results		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



ALAN WHITE DESIGN

X-BEAM		
Loadcase No.	Ultimate Moment	Allowable Moment
1 UDL	73.07	48.71
2 Point	65.48	43.65
3 Third	55.50	37.00
4 Quarter	73.80	49.20

Loadcase No.	Ultimate Shear	Allowable Shear
5 End Shear	67.30	44.87

Max Allowable Moment = 37 kNm

Max Allowable Shear = 44 kN

From 3m X-Beam Analysis with restraints to compression chord at 1.0m c/c



ALAN WHITE DESIGN

For simply supported Apollo single X-BEAM TO EUROCODE EN 1999-1

Allowable Bending Moment	37 kNm
Allowable Shear	44 kN

Type of Load		Clear span (m)																
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Uniformly Distributed load	kN/m	<i>44.0</i>	<i>29.3</i>	18.5	11.8	8.2	6.0	4.6	3.7	3.0	2.4	2.1	1.8	1.5	1.3	1.2	1.0	0.9
Total UDL	kN	<i>88</i>	<i>88.0</i>	74.0	59.2	49.3	42.3	37.0	32.9	29.6	26.9	24.7	22.8	21.1	19.7	18.5	17.4	16.4
Single point load (mid Point)	kN	74.0	49.3	37.0	29.6	24.7	21.1	18.5	16.4	14.8	13.5	12.3	11.4	10.6	9.9	9.3	8.7	8.2
Two point loads (third points)	Each kN	<i>44.0</i>	37.0	27.8	22.2	18.5	15.9	13.9	12.3	11.1	10.1	9.3	8.5	7.9	7.4	6.9	6.5	6.2
Three point loads (quarter points)	Each kN	<i>29.3</i>	24.7	18.5	14.8	12.3	10.6	9.3	8.2	7.4	6.7	6.2	5.7	5.3	4.9	4.6	4.4	4.1


- 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 nodes. All scaffolds and structures should be checked by a qualified structural engineer. Loads indicated in italics and shaded are limited by shear.
 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. Compression chord restraint required at 1m c/c

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	6m X-Beam Results		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



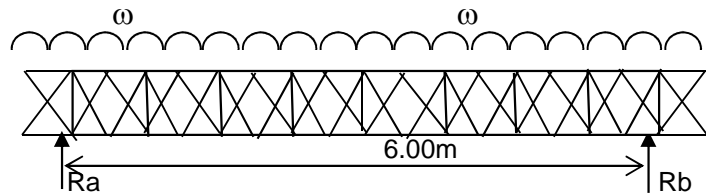
ALAN WHITE DESIGN

6m X-Beam Results

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	6m X-Beam Load Combination 1			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb. 1 UDL load 10kN/m applied along beam

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.42	2.50
	Shear	V_{Rd}	32.91	4.57	7.20
	Tension	$N_{o,Rd}$	90.13	31.31	2.88
	Compression	$N_{b,Rd}$	102.86	91.72	1.12
	Deflection	d	60	10.28	5.84
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.83
Vertical	Moment	$M_{c,Rd}$	0.91	0.08	11.48
	Shear	V_{Rd}	47.79	0.21	225.42
	Tension	$N_{o,Rd}$	90.13	0.53	170.06
	Compression	$N_{b,Rd}$	107.35	24.92	4.31
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	3.79
Diagonal	Tension	$N_{o,Rd}$	48.70	20.46	2.38
	Compression	$N_{b,Rd}$	62.76	29.74	2.11
Factor					0.83



$$\text{Max Moment} = \frac{ML^2}{8}$$

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

$$W = \frac{1.5 \times 10 \times 6}{2} = 15.00 \text{ kN}$$

apply factor from above

$$W_f = \frac{15 \times 0.83}{1} = 12.45 \text{ kN}$$

so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= \frac{W_f \times L^2}{8} \\ &= \frac{(12.45 \times 6^2)}{8} \\ &= 56.03 \text{ kNm} \end{aligned}$$

and for allowable value

$$\begin{aligned} \text{allowable max moment} &= \frac{56.03}{1.50} \\ &= 37.35 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	56.03 kNm
	Allowable	37.35 kNm

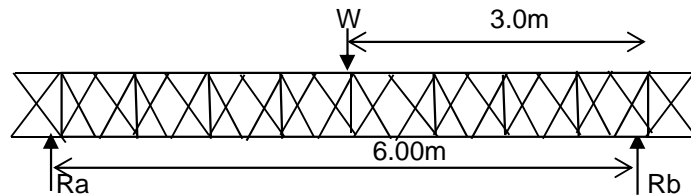
CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	6m X-Beam Load Combination 2		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



ALAN WHITE DESIGN

Load Comb. 2 Point load 10kN load applied at midspan of beam

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.07	14.69
	Shear	V_{Rd}	32.91	0.18	179.83
	Tension	$N_{o,Rd}$	90.13	13.86	6.50
	Compression	$N_{b,Rd}$	102.86	29.62	3.47
	Deflection	d	60	3.14	19.11
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	2.94
Vertical	Moment	$M_{c,Rd}$	0.91	0.02	45.36
	Shear	V_{Rd}	47.79	0.06	853.37
	Tension	$N_{o,Rd}$	90.13	0.02	4506.60
	Compression	$N_{b,Rd}$	107.35	6.22	17.26
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	13.31
Diagonal	Tension	$N_{o,Rd}$	48.70	5.04	9.66
	Compression	$N_{b,Rd}$	62.76	5.21	12.05
			Factor		2.94



Max Moment = $ML/4$

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

$$W = 1.50 * 10 = 15.00 \text{ kN}$$

apply factor from above

$$Wf = 15 * 2.94 = 44.10 \text{ kN}$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } Mu &= Wf * L / 4 \\ &= 44.10 * 6 / 4 \\ &= 66.15 \text{ kNm} \end{aligned}$$

and for allowable value

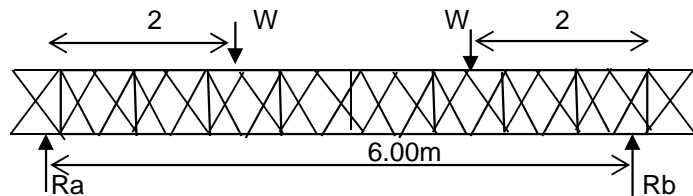
$$\begin{aligned} \text{allowable max moment} &= 66.15 / 1.50 \\ &= 44.10 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	66.15 kNm
	Allowable	44.10 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	6m X-Beam Load Combination 3			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb. 3 PL at third points 10kN load applied at each of the two third points

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.096	10.87
	Shear	V_{Rd}	32.91	0.258	127.55
	Tension	$N_{o,Rd}$	90.13	14.7	6.13
	Compression	$N_{b,Rd}$	102.86	43.55	2.36
	Deflection	d	60	4.89	12.27
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	2.03
Vertical	Moment	$M_{c,Rd}$	0.91	0.038	23.87
	Shear	V_{Rd}	47.79	0.108	442.49
	Tension	$N_{o,Rd}$	90.13	0.001	90132.00
	Compression	$N_{b,Rd}$	107.35	6.87	15.63
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	10.25
Diagonal	Tension	$N_{o,Rd}$	48.70	9.7	5.02
	Compression	$N_{b,Rd}$	62.76	10.03	6.26
			Factor		2.03



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Moment} = \frac{ML}{3}$$

so for ultimate condition

$$W = \frac{1.50 \times 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = \frac{15.00 \times 2.03}{30.45} \text{ kN}$$

so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= \frac{W_f \times L}{3} \\ &= \frac{(30.45 \times 6)}{3} \\ &= 60.90 \text{ kNm} \end{aligned}$$

and for allowable value

$$\begin{aligned} \text{allowable max moment} &= \frac{60.9}{1.50} \\ &= 40.60 \text{ kNm} \end{aligned}$$

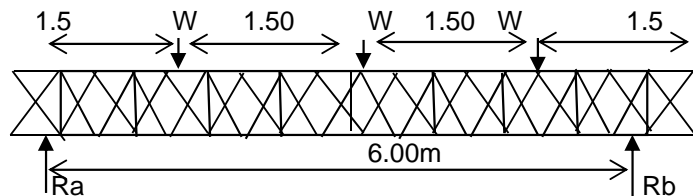
Moment values	Ultimate	60.90 kNm
	Allowable	40.60 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	6m X-Beam Load Combination 4		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



Load Comb. 4 PL at quarter points
10kN load applied at each of the three quarter points

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.103	10.13
	Shear	V_{Rd}	32.91	0.298	110.43
	Tension	$N_{o,Rd}$	90.13	21.14	4.26
	Compression	$N_{b,Rd}$	102.86	61.47	1.67
	Deflection	d	60.00	6.8	8.82
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	1.49
Vertical	Moment	$M_{c,Rd}$	0.91	0.075	12.09
	Shear	V_{Rd}	47.79	0.181	264.03
	Tension	$N_{o,Rd}$	90.13	3.34	26.99
	Compression	$N_{b,Rd}$	107.35	10.1	10.63
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	6.19
Diagonal	Tension	$N_{o,Rd}$	48.70	14.86	3.28
	Compression	$N_{b,Rd}$	62.76	18.34	3.42
Factor					1.49



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Moment} = \frac{ML}{2}$$

so for ultimate condition

$$W = \frac{1.50 \times 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = 15.00 \times 1.49 = 22.35 \text{ kN}$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= W_f \times L / 2 \\ &= (22.35 \times 6) / 2 \\ &= 67.05 \text{ kNm} \end{aligned}$$

and for allowable value

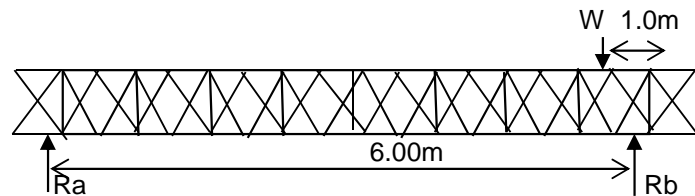
$$\begin{aligned} \text{allowable max moment} &= 67.05 / 1.50 \\ &= 44.70 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	67.05 kNn
	Allowable	44.70 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	6m X-Beam Load Combination 5			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb. 5 End Shear 10kN load applied at a 1.0m distance from the support

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.08	13.91
	Shear	V_{Rd}	32.91	0.17	198.25
	Tension	$N_{o,Rd}$	90.13	6.92	13.02
	Compression	$N_{b,Rd}$	102.86	15.75	6.53
	Deflection	d	60.00	1.83	32.79
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	4.77
Vertical	Moment	$M_{c,Rd}$	0.91	0.02	50.40
	Shear	V_{Rd}	47.79	1.04	45.86
	Tension	$N_{o,Rd}$	90.13	0.10	901.32
	Compression	$N_{b,Rd}$	107.35	5.52	19.45
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	14.95
Diagonal	Tension	$N_{o,Rd}$	48.70	6.43	7.57
	Compression	$N_{b,Rd}$	62.76	6.62	9.48
Factor					4.77



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Shear } R_b = W * 5/6$$

so for ultimate condition

$$W = 1.50 * 10 = 15.00 \text{ kN}$$

apply factor from above

$$W_f = 15.0 * 4.77 = 71.55 \text{ kN}$$


so maximum shear is as above

$$\begin{aligned} \text{Ultimate } Q_u &= W_f * 5/6 \\ &= (71.55 * 5)/6 \\ &= 59.63 \text{ kN} \end{aligned}$$

and for allowable value

$$\begin{aligned} \text{allowable max shear} &= 59.63/1.50 \\ &= 39.75 \text{ kN} \end{aligned}$$

Shear values	Ultimate	59.63 kN
	Allowable	39.75 kN

CALCULATION SHEET	Project : Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element : 6m X-Beam Results			
	Job Number : R0076	By : eas	Date:Oct 14	
	Document No : 001B	Checked :anw	Date:Oct 14	

X-BEAM		
Loadcase	Ultimate	Allowable
No.	Moment	Moment
1 UDL	56.03	37.35
2 Point	66.15	44.10
3 Third	60.90	40.60
4 Quarter	67.05	44.70

Loadcase	Ultimate	Allowable
No.	Shear	Shear
5 End Shear	59.63	39.75

Max Allowable Moment = 37 kNm

Max Allowable Shear = 39 kN

From 6m X-Beam Results with restraint to compression chord at 1.0m c/c:



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For simply supported Apollo single X-BEAM TO EUROCODE EN 1999-1

Allowable Bending Moment	37 kNm
Allowable Shear	39 kN

Allowable loads for load distributions

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Uniformly Distributed load	kN/m	<i>39.0</i>	<i>26.0</i>	18.5	11.8	8.2	6.0	4.6	3.7	3.0	2.4	2.1	1.8	1.5	1.3	1.2	1.0	0.9
Total UDL	kN	<i>78.0</i>	<i>78.0</i>	74.0	59.2	49.3	42.3	37.0	32.9	29.6	26.9	24.7	22.8	21.1	19.7	18.5	17.4	16.4
Single point load (mid Point)	kN	74.0	49.3	37.0	29.6	24.7	21.1	18.5	16.4	14.8	13.5	12.3	11.4	10.6	9.9	9.3	8.7	8.2
Two point loads (third points)	Each kN	<i>39.0</i>	37.0	27.8	22.2	18.5	15.9	13.9	12.3	11.1	10.1	9.3	8.5	7.9	7.4	6.9	6.5	6.2
Three point loads (quarter points)	Each kN	<i>26.0</i>	24.7	18.5	14.8	12.3	10.6	9.3	8.2	7.4	6.7	6.2	5.7	5.3	4.9	4.6	4.4	4.1

- 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 nodes. All scaffolds and structures should be checked by a qualified structural engineer. Loads indicated in italics and shaded are limited by shear.
 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. Compression chord restraint required at 1m c/c

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	9m X-Beam Results		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



ALAN WHITE DESIGN

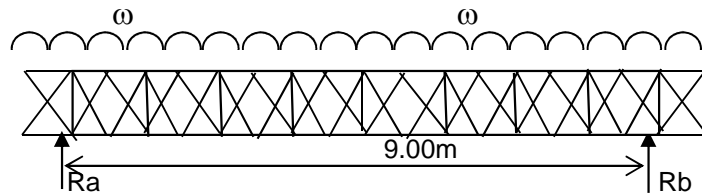
9m X-Beam Results

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	9m X-Beam Load Combination 1		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



Load Comb. 1 UDL load 10kN/m applied along beam

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.45	2.33
	Shear	V_{Rd}	32.91	4.53	7.26
	Tension	$N_{o,Rd}$	90.13	71.55	1.26
	Compression	$N_{b,Rd}$	102.86	212.40	0.48
	Deflection	d	90	70.60	1.27
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.42
Vertical	Moment	$M_{c,Rd}$	0.91	0.14	6.53
	Shear	V_{Rd}	47.79	0.38	127.10
	Tension	$N_{o,Rd}$	90.13	0.00	90132.00
	Compression	$N_{b,Rd}$	107.35	14.87	7.22
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	3.77
Diagonal	Tension	$N_{o,Rd}$	48.70	1.76	27.67
	Compression	$N_{b,Rd}$	62.76	34.73	1.81
Factor					0.42



Max Moment= $ML^2/8$

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

$W = 1.5 * 10$
 15.00 kN

apply factor from above

$Wf = 15 * 0.42$
 $= 6.30 \text{ kN}$


so maximum moment is as above

Ultimate $M_u = Wf * 9^2 / 8$
 $= (6.3 * 9^2) / 8$
 $= 63.79 \text{ kNm}$

and for allowable value

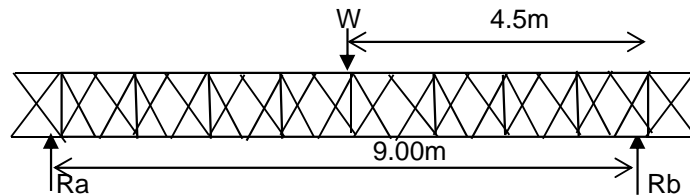
allowable max moment= $63.79 / 1.50$
 $= 42.53 \text{ kNm}$

Moment values	Ultimate	63.79 kNm
	Allowable	42.53 kNm

CALCULATION SHEET	Project : Apollo X-beam to Eurocode		 ALAN WHITE DESIGN	
	Element : 9m X-Beam Load Combination 2			
	Job Number : R0076	By : eas		Date: Oct 14
	Document No : 001B	Checked : anw		Date: Oct 14

Load Comb. 2 Point load 10kN load applied at midspan of beam

Element	Action	Formula	Ultimate	Calculated	Factor	
Boom	Moment	$M_{c,Rd}$	1.04	0.085	12.27	
	Shear	V_{Rd}	32.91	0.205	160.53	
	Tension	$N_{o,Rd}$	90.13	24.1	3.74	
	Compression	$N_{b,Rd}$	102.86	44.28	2.32	
	Deflection	d		90.00	13.9	6.47
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$			1.20	2.35
Vertical	Moment	$M_{c,Rd}$	0.91	0.034	26.68	
	Shear	V_{Rd}	47.79	0.072	663.73	
	Tension	$N_{o,Rd}$	90.13	3.44	26.20	
	Compression	$N_{b,Rd}$	107.35	3.52	30.50	
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$			0.78	12.50
Diagonal	Tension	$N_{o,Rd}$	48.70	5.03	9.68	
	Compression	$N_{b,Rd}$	62.76	8.99	6.98	
Factor					2.32	



$$\text{Max Moment} = \frac{ML}{4}$$

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

$$W = 1.50 \times 10$$

$$= 15.00 \text{ kN}$$

apply factor from above

$$W_f = 15 \times 2.32$$

$$= 34.80 \text{ kN}$$

so maximum moment is as above

$$\text{Ultimate } M_u = \frac{W_f \times 9}{4}$$

$$= \frac{34.8 \times 9}{4}$$


$$= 78.30 \text{ kNm}$$

and for allowable value

$$\text{allowable max moment} = \frac{78.30}{1.50}$$

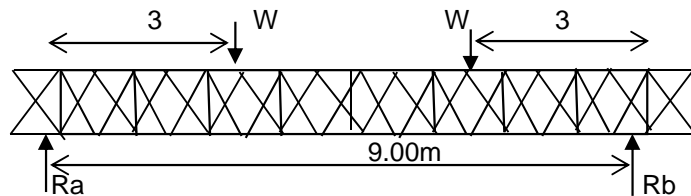
$$= 52.20 \text{ kNm}$$

Moment values	Ultimate	78.30 kNm
	Allowable	52.20 kNm

CALCULATION SHEET	Project : Apollo X-beam to Eurocode		 ALAN WHITE DESIGN	
	Element : 9m X-Beam Load Combination 3			
	Job Number : R0076	By : eas		Date: Oct 14
	Document No : 001B	Checked : anw		Date: Oct 14

Load Comb. 3 PL at third points 10kN load applied at each of the two third points

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.119	8.77
	Shear	V_{Rd}	32.91	0.307	107.20
	Tension	$N_{o,Rd}$	90.13	22.05	4.09
	Compression	$N_{b,Rd}$	102.86	65.7	1.57
	Deflection	d	90.00	22.34	4.03
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	1.38
Vertical	Moment	$M_{c,Rd}$	0.91	0.04	22.68
	Shear	V_{Rd}	47.79	0.111	430.53
	Tension	$N_{o,Rd}$	90.13	0.33	273.13
	Compression	$N_{b,Rd}$	107.35	6.83	15.72
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	10.09
Diagonal	Tension	$N_{o,Rd}$	48.70	9.8	4.97
	Compression	$N_{b,Rd}$	62.76	10.22	6.14
Factor					1.38



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Moment} = \frac{ML}{3}$$

so for ultimate condition

$$W = \frac{1.50 \times 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = \frac{15.00 \times 1.38}{1} = 20.70 \text{ kN}$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= \frac{W_f \times 9}{3} \\ &= \frac{(20.70 \times 9)}{3} \\ &= 62.10 \text{ kNm} \end{aligned}$$

and for allowable value

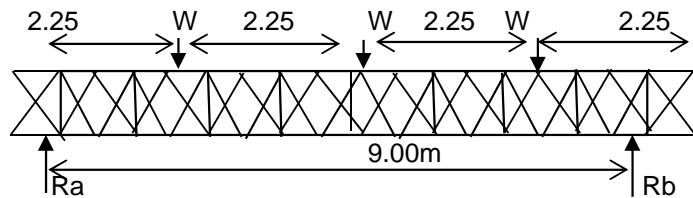
$$\begin{aligned} \text{allowable max moment} &= \frac{62.10}{1.50} \\ &= 41.40 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	62.10 kNm
	Allowable	41.40 kNm

CALCULATION SHEET	Project : Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element : 9m X-Beam load Combination 4			
	Job Number : R0076	By : eas	Date: Oct 14	
	Document No : 001B	Checked : anw	Date: Oct 14	

Load Comb. 4 PL at quarter points
10kN load applied at each of the three quarter points

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.137	7.61
	Shear	V_{Rd}	32.91	0.391	84.17
	Tension	$N_{o,Rd}$	90.13	33.55	2.69
	Compression	$N_{b,Rd}$	102.86	86.67	1.19
	Deflection	d	90.00	19.36	4.65
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	1.06
Vertical	Moment	$M_{c,Rd}$	0.91	0.058	15.64
	Shear	V_{Rd}	47.79	0.163	293.18
	Tension	$N_{o,Rd}$	90.13	3.92	22.99
	Compression	$N_{b,Rd}$	107.35	10.17	10.56
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	6.85
Diagonal	Tension	$N_{o,Rd}$	48.70	14.54	3.35
	Compression	$N_{b,Rd}$	62.76	15.13	4.15
Factor					1.06



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Moment} = \frac{ML}{2}$$

so for ultimate condition

$$W = \frac{1.50 \times 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = 15.00 \times 1.06 = 15.90 \text{ kN}$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= W_f \times 9/2 \\ &= (15.90 \times 9)/2 \\ &= 71.55 \text{ kNm} \end{aligned}$$

and for allowable value

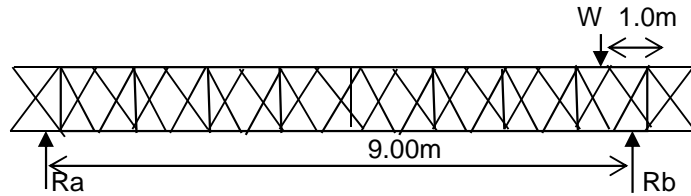
$$\begin{aligned} \text{allowable max moment} &= 71.55/1.50 \\ &= 47.70 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	71.55 kNm
	Allowable	47.70 kNm

CALCULATION SHEET	Project : Apollo X-beam to Eurocode		 ALAN WHITE DESIGN	
	Element : 9m X-Beam Load Combination 5			
	Job Number : R0076	By : eas		Date: Oct 14
	Document No : 001B	Checked : anw		Date: Oct 14

Load Comb. 5 End Shear 10kN load applied at a 1m distance from the support

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.071	14.69
	Shear	V_{Rd}	32.91	0.207	158.98
	Tension	$N_{o,Rd}$	90.13	8.91	10.12
	Compression	$N_{b,Rd}$	102.86	18.71	5.50
	Deflection	d	90.00	3.13	28.75
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	4.26
Vertical	Moment	$M_{c,Rd}$	0.91	0.023	39.44
	Shear	V_{Rd}	47.79	0.054	884.98
	Tension	$N_{o,Rd}$	90.13	0.15	600.88
	Compression	$N_{b,Rd}$	107.35	6.64	16.17
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	14.68
Diagonal	Tension	$N_{o,Rd}$	48.70	8.24	5.91
	Compression	$N_{b,Rd}$	62.76	8.53	7.36
Factor					4.26



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Shear } R_b = W * 8/9$$

so for ultimate condition

$$W = 1.50 * 10 = 15.00 \text{ kN}$$

apply factor from above

$$W_f = 15.00 * 4.26 = 63.90 \text{ kN}$$

so maximum shear is as above

$$\begin{aligned} \text{Ultimate } Q_u &= W_f * 8/9 \\ &= (63.9 * 8) / 9 \\ &= 56.80 \text{ kN} \end{aligned}$$

and for allowable value

$$\begin{aligned} \text{allowable max shear} &= 56.80 / 1.50 \\ &= 37.87 \text{ kN} \end{aligned}$$

Shear values	Ultimate	56.80 kN
	Allowable	37.87 kN

CALCULATION SHEET	Project : Apollo X-beam to Eurocode		
	Element : 9m X-Beam Results		
	Job Number : R0076	By : eas	Date: Oct 14
	Document No : 001B	Checked : anw	Date: Oct 14



X-BEAM		
Loadcase No.	Ultimate Moment	Allowable Moment
1 UDL	63.79	42.53
2 Point	78.30	52.20
3 Third	62.10	41.40
4 Quarter	71.55	47.70

Loadcase No.	Ultimate Shear	Allowable Shear
5 End Shear	56.80	37.87

Max Allowable Moment = 41 kNm

Max Allowable Shear = 37 kN

From 9m X-Beam Results with restraint to compression chord at 1.0m c/c:



For simply supported Apollo single X-BEAM TO EUROCODE EN 1999-1

Allowable Bending Moment	41 kNm
Allowable Shear	37 kN

Allowable loads for load distributions

Type of Load	Clear span (m)																	
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Uniformly Distributed load	kN/m	37.0	24.7	18.5	13.1	9.1	6.7	5.1	4.0	3.3	2.7	2.3	1.9	1.7	1.5	1.3	1.1	1.0
Total UDL	kN	74.0	74.0	74.0	65.6	54.7	46.9	41.0	36.4	32.8	29.8	27.3	25.2	23.4	21.9	20.5	19.3	18.2
Single point load (mid Point)	kN	74.0	54.7	41.0	32.8	27.3	23.4	20.5	18.2	16.4	14.9	13.7	12.6	11.7	10.9	10.3	9.6	9.1
Two point loads (third points)	Each kN	37.0	37.0	30.8	24.6	20.5	17.6	15.4	13.7	12.3	11.2	10.3	9.5	8.8	8.2	7.7	7.2	6.8
Three point loads (quarter points)	Each kN	24.7	24.7	20.5	16.4	13.7	11.7	10.3	9.1	8.2	7.5	6.8	6.3	5.9	5.5	5.1	4.8	4.6

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.

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	12m X-Beam Results		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



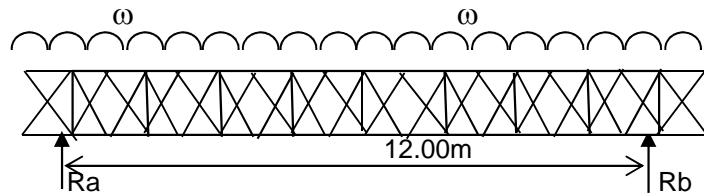
ALAN WHITE DESIGN

12m X-Beam Results

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	12m X-Beam Load Combination 1			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb. 1 UDL load 10kN/m applied along beam

Element	Action	Formula	Ultimate	Calculated	Factor	
Boom	Moment	$M_{c,Rd}$	1.04	0.58	1.79	
	Shear	V_{Rd}	32.91	4.94	6.66	
	Tension	$N_{o,Rd}$	90.13	127.89	0.70	
	Compression	$N_{b,Rd}$	102.86	381.38	0.27	
	Deflection	d		120.00	213.81	0.56
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$			1.00	0.24
Vertical	Moment	$M_{c,Rd}$	0.91	0.34	2.66	
	Shear	V_{Rd}	47.79	0.87	54.87	
	Tension	$N_{o,Rd}$	90.13	7.83	11.52	
	Compression	$N_{b,Rd}$	107.35	62.73	1.71	
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$			1.00	1.13
Diagonal	Tension	$N_{o,Rd}$	48.70	77.03	0.63	
	Compression	$N_{b,Rd}$	62.76	90.78	0.69	
Factor					0.24	



$$\text{Max Moment} = \frac{ML^2}{8}$$

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

$$W = \frac{1.5 \times 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = \frac{15 \times 0.24}{3.60} \text{ kN}$$

so maximum moment is as above

$$\begin{aligned} \text{Ultimate } \mu_u &= \frac{W_f \times 12^2}{8} \\ &= \frac{(3.6 \times 12^2)}{8} \\ &= 64.80 \text{ kNm} \end{aligned}$$

and for allowable value

$$\begin{aligned} \text{allowable max moment} &= \frac{64.80}{1.50} \\ &= 43.20 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	64.80 kNm
	Allowable	43.20 kNm

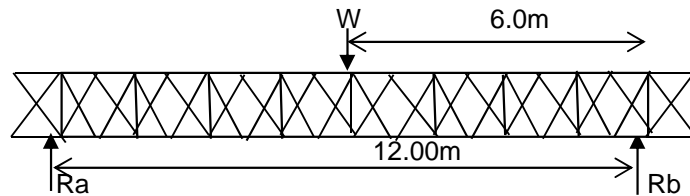
CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	12m X-Beam Load Combination 2		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



ALAN WHITE DESIGN

Load Comb. 2 Point load 10kN load applied at midspan of beam

Element	Action	Formula	Ultimate	Calculated	Factor	
Boom	Moment	$M_{c,Rd}$	1.04	0.104	10.03	
	Shear	V_{Rd}	32.91	0.244	134.87	
	Tension	$N_{o,Rd}$	90.13	30.55	2.95	
	Compression	$N_{b,Rd}$	102.86	63.69	1.61	
	Deflection	d		120.00	21.33	5.63
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$			1.00	1.44
Vertical	Moment	$M_{c,Rd}$	0.91	0.021	43.20	
	Shear	V_{Rd}	47.79	0.058	823.95	
	Tension	$N_{o,Rd}$	90.13	0.48	187.78	
	Compression	$N_{b,Rd}$	107.35	5.98	17.95	
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$			1.00	13.55
Diagonal	Tension	$N_{o,Rd}$	48.70	5.11	9.53	
	Compression	$N_{b,Rd}$	62.76	5.43	11.56	
Factor					1.44	



$$\text{Max Moment} = \frac{ML}{4}$$

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

$$W = 1.50 \cdot 10$$

$$= 15.00 \text{ kN}$$

apply factor from above

$$W_f = 15 \cdot 1.44$$

$$= 21.60 \text{ kN}$$

so maximum moment is as above

$$\text{Ultimate } M_u = \frac{W_f \cdot L}{4}$$

$$= \frac{21.6 \cdot 12}{4}$$


$$= 64.80 \text{ kNm}$$

and for allowable value

$$\text{allowable max moment} = \frac{64.80}{1.50}$$

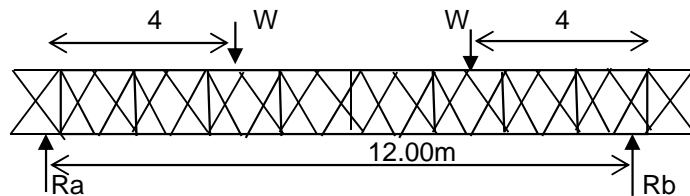
$$= 43.20 \text{ kNm}$$

Moment values	Ultimate	64.80 kNm
	Allowable	43.20 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	12m X-Beam Load Combination 3			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb. 3 PL at third points 10kN load applied at each of the two third points

Element	Action	Formula	Ultimate	Calculated	Factor	
Boom	Moment	$M_{c,Rd}$	1.04	0.14	7.35	
	Shear	V_{Rd}	32.91	0.36	91.41	
	Tension	$N_{o,Rd}$	90.13	29.43	3.06	
	Compression	$N_{b,Rd}$	102.86	88.17	1.17	
	Deflection	d		120.00	34.10	3.52
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$			1.00	1.04
Vertical	Moment	$M_{c,Rd}$	0.91	0.04	22.12	
	Shear	V_{Rd}	47.79	0.11	422.91	
	Tension	$N_{o,Rd}$	90.13	0.81	111.27	
	Compression	$N_{b,Rd}$	107.35	6.79	15.81	
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$			1.00	10.03
Diagonal	Tension	$N_{o,Rd}$	48.70	9.86	4.94	
	Compression	$N_{b,Rd}$	62.76	10.40	6.03	
			Factor		1.04	



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Moment} = \frac{ML}{3}$$

so for ultimate condition

$$W = \frac{1.50 \times 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = \frac{15.00 \times 1.04}{15.00} = 15.60 \text{ kN}$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= \frac{W_f \times L}{3} \\ &= \frac{15.60 \times 12}{3} \\ &= 62.40 \text{ kNm} \end{aligned}$$

and for allowable value

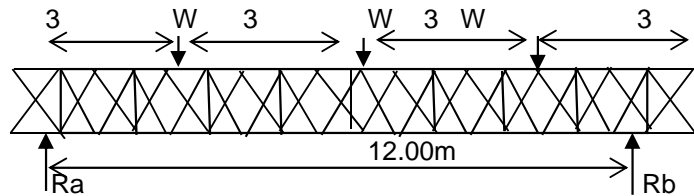
$$\begin{aligned} \text{allowable max moment} &= \frac{62.40}{1.50} \\ &= 41.60 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	62.40 kNm
	Allowable	41.60 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	12m X-Beam Load Combination 4			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb. 4 Load at quarter points
10kN load applied at each of the three quarter points

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.175	5.96
	Shear	V_{Rd}	32.91	0.469	70.17
	Tension	$N_{o,Rd}$	90.13	46.52	1.94
	Compression	$N_{b,Rd}$	102.86	127.58	0.81
	Deflection	d	120.00	47	2.55
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.73
Vertical	Moment	$M_{c,Rd}$	0.91	0.06	15.12
	Shear	V_{Rd}	47.79	0.167	286.16
	Tension	$N_{o,Rd}$	90.13	0.89	101.27
	Compression	$N_{b,Rd}$	107.35	10.06	10.67
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	6.80
Diagonal	Tension	$N_{o,Rd}$	48.70	14.61	3.33
	Compression	$N_{b,Rd}$	62.76	15.36	4.09
Factor					0.73



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Moment} = \frac{ML}{2}$$

so for ultimate condition

$$W = \frac{1.50 \times 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = \frac{15.00 \times 0.73}{1} = 10.95 \text{ kN}$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= W_f \times 12 / 2 \\ &= (10.95 \times 12) / 2 \\ &= 65.70 \text{ kNm} \end{aligned}$$

and for allowable value

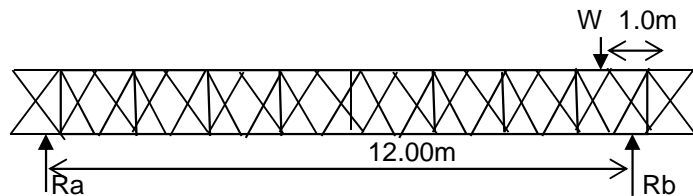
$$\begin{aligned} \text{allowable max moment} &= \frac{65.70}{1.50} \\ &= 43.80 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	65.70 kNm
	Allowable	43.80 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	12m X-Beam Load Combination 5			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb. 5 End Shear 10kN load applied at a 1.0m distance from the support

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.07	14.29
	Shear	V_{Rd}	32.91	0.21	153.78
	Tension	$N_{o,Rd}$	90.13	8.83	10.21
	Compression	$N_{b,Rd}$	102.86	19.88	5.17
	Deflection	d	120.00	5.77	20.80
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	4.04
Vertical	Moment	$M_{c,Rd}$	0.91	0.02	37.80
	Shear	V_{Rd}	47.79	0.06	838.40
	Tension	$N_{o,Rd}$	90.13	0.16	563.33
	Compression	$N_{b,Rd}$	107.35	6.90	15.56
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	11.77
Diagonal	Tension	$N_{o,Rd}$	48.70	8.57	5.68
	Compression	$N_{b,Rd}$	62.76	8.92	7.04
Factor					4.04



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Shear } R_b = W * 8/9$$

so for ultimate condition

$$W = \frac{1.50 * 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = 15.0 * 4.04 = 60.60 \text{ kN}$$

so maximum shear is as above

$$\begin{aligned} \text{Ultimate } Q_u &= W_f * 11/12 \\ &= (60.6 * 11)/12 \\ &= 55.55 \text{ kN} \end{aligned}$$

and for allowable value

$$\begin{aligned} \text{allowable max shear} &= 55.55/1.50 \\ &= 37.03 \text{ kN} \end{aligned}$$

Shear values	Ultimate	55.55 kN
	Allowable	37.03 kN

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	12m X-Beam Results		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



ALAN WHITE DESIGN

X-BEAM		
Loadcase	Ultimate	Allowable
No.	Moment	Moment
1 UDL	64.80	43.20
2 Point	64.80	43.20
3 Third	62.40	41.60
4 Quarter	65.70	43.80

Loadcase	Ultimate	Allowable
No.	Shear	Shear
5 End Shear	55.55	37.03

Max Allowable Moment = 41 kNm

Max Allowable Shear = 37 kN

From 12m X-Beam Results with restraint to compression chord at 1.0m c/c:

For simply supported Apollo single X-BEAM TO EUROCODE EN 1999-1



ALAN WHITE DESIGN

Allowable Bending Moment	41 kNm
Allowable Shear	37 kN

Allowable loads for load distributions

Type of Load		Clear span (m)																
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Uniformly Distributed load	kN/m	37.0	24.7	18.5	13.1	9.1	6.7	5.1	4.0	3.3	2.7	2.3	1.9	1.7	1.5	1.3	1.1	1.0
Total UDL	kN	74.0	74.0	74.0	65.6	54.7	46.9	41.0	36.4	32.8	29.8	27.3	25.2	23.4	21.9	20.5	19.3	18.2
Single point load (mid Point)	kN	74.0	54.7	41.0	32.8	27.3	23.4	20.5	18.2	16.4	14.9	13.7	12.6	11.7	10.9	10.3	9.6	9.1
Two point loads (third points)	Each kN	37.0	37.0	30.8	24.6	20.5	17.6	15.4	13.7	12.3	11.2	10.3	9.5	8.8	8.2	7.7	7.2	6.8
Three point loads (quarter points)	Each kN	24.7	24.7	20.5	16.4	13.7	11.7	10.3	9.1	8.2	7.5	6.8	6.3	5.9	5.5	5.1	4.8	4.6


- 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 nodes. All scaffolds and structures should be checked by a qualified structural engineer. Loads indicated in italics and shaded are limited by shear.
 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. Compression chord restraint required at 1m c/c

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	15m X-Beam Results		
	Job Number :	R0076	By : eas	Date:Oct 15
	Document No :	001	Checked :anw	Date:Oct 15



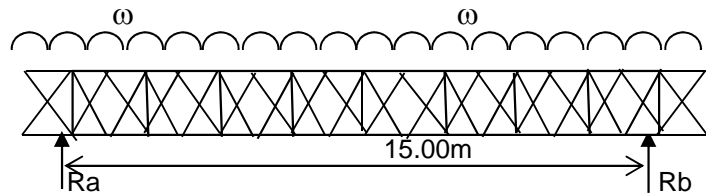
ALAN WHITE DESIGN

15m X-Beam Results

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	15m X-Beam Load Combination 1			
	Job Number :	R0076	By : eas	Date: Oct 15	
	Document No :	001	Checked : anw	Date: Oct 15	

Load Comb. 1 UDL load 10kN/m applied along beam

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.76	1.38
	Shear	V_{Rd}	32.91	5.56	5.92
	Tension	$N_{o,Rd}$	90.13	200.37	0.45
	Compression	$N_{b,Rd}$	102.86	598.65	0.17
	Deflection	d	150.00	343.21	0.44
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.16
Vertical	Moment	$M_{c,Rd}$	0.91	0.26	3.52
	Shear	V_{Rd}	47.79	0.71	67.79
	Tension	$N_{o,Rd}$	90.13	5.50	16.39
	Compression	$N_{b,Rd}$	107.35	53.64	2.00
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	1.38
Diagonal	Tension	$N_{o,Rd}$	48.70	63.01	0.77
	Compression	$N_{b,Rd}$	62.76	75.3	0.83
Factor					0.16



$$\text{Max Moment} = \frac{ML^2}{8}$$

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

$$W = \frac{1.5 \times 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = \frac{15 \times 0.16}{1} = 2.40 \text{ kN}$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= \frac{W_f \times 15^2}{8} \\ &= \frac{(2.40 \times 15^2)}{8} \\ &= 67.50 \text{ kNm} \end{aligned}$$

and for allowable value

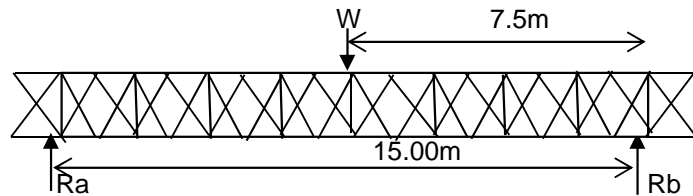
$$\begin{aligned} \text{allowable max moment} &= \frac{67.50}{1.50} \\ &= 45.00 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	67.50 kNm
	Allowable	45.00 kNm

CALCULATION SHEET	Project : Apollo X-beam to Eurocode		 ALAN WHITE DESIGN	
	Element : 15m X-Beam Load Combination 2			
	Job Number : R0076	By : eas		Date: Oct 15
	Document No : 001	Checked : anw		Date: Oct 15

Load Comb. 2 Point load 10kN load applied at midspan of beam

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.088	11.85
	Shear	V_{Rd}	32.91	0.197	167.05
	Tension	$N_{o,Rd}$	90.13	41.14	2.19
	Compression	$N_{b,Rd}$	102.86	79.06	1.30
	Deflection	d	150.00	41.17	3.64
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	1.20
Vertical	Moment	$M_{c,Rd}$	0.91	0.034	26.68
	Shear	V_{Rd}	47.79	0.072	663.73
	Tension	$N_{o,Rd}$	90.13	3.67	24.56
	Compression	$N_{b,Rd}$	107.35	3.54	30.32
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	15.60
Diagonal	Tension	$N_{o,Rd}$	48.70	5.18	9.40
	Compression	$N_{b,Rd}$	62.76	9.06	6.93
Factor					1.20



Max Moment = $ML/4$

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

$$W = 1.50 \times 10$$

$$= 15.00 \text{ kN}$$

apply factor from above

$$W_f = 15 \times 1.20$$

$$= 18.00 \text{ kN}$$

so maximum moment is as above

$$\text{Ultimate } M_u = W_f \times 15/4$$

$$= 18.00 \times 15/4$$


$$= 67.50 \text{ kNm}$$

and for allowable value

$$\text{allowable max moment} = 67.50/1.50$$

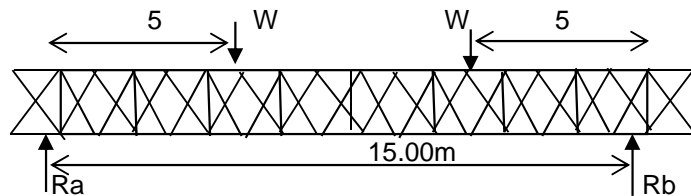
$$= 45.00 \text{ kNm}$$

Moment values	Ultimate	67.50 kNm
	Allowable	45.00 kNm

CALCULATION SHEET	Project : Apollo X-beam to Eurocode		 ALAN WHITE DESIGN	
	Element : 15m X-Beam Load Combination 3			
	Job Number : R0076	By : eas		Date: Oct 15
	Document No : 001	Checked : anw		Date: Oct 15

Load Comb. 3 PL at third points 10kN load applied at each of the two third points

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.166	6.28
	Shear	V_{Rd}	32.91	0.414	79.49
	Tension	$N_{o,Rd}$	90.13	36.98	2.44
	Compression	$N_{b,Rd}$	102.86	110.94	0.93
	Deflection	d	150.00	66.04	2.27
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.84
Vertical	Moment	$M_{c,Rd}$	0.91	0.041	22.12
	Shear	V_{Rd}	47.79	0.113	422.91
	Tension	$N_{o,Rd}$	90.13	0.81	111.27
	Compression	$N_{b,Rd}$	107.35	6.79	15.81
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	10.03
Diagonal	Tension	$N_{o,Rd}$	48.70	9.86	4.94
	Compression	$N_{b,Rd}$	62.76	10.4	6.03
Factor					0.84



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Moment} = \frac{ML}{3}$$

so for ultimate condition

$$W = \frac{1.50 \times 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = 15.00 \times 0.84 = 12.60 \text{ kN}$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= \frac{W_f \times L}{3} \\ &= \frac{(12.60 \times 15)}{3} \\ &= 63.00 \text{ kNm} \end{aligned}$$

and for allowable value

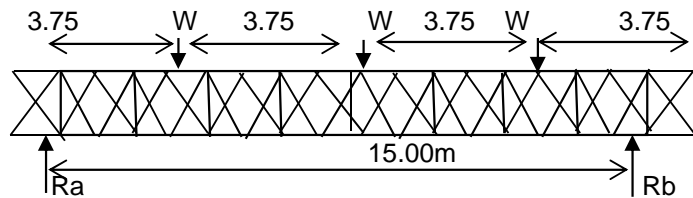
$$\begin{aligned} \text{allowable max moment} &= \frac{63.00}{1.50} \\ &= 42.00 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	63.00 kNm
	Allowable	42.00 kNm

CALCULATION SHEET	Project : Apollo X-beam to Eurocode		 ALAN WHITE DESIGN	
	Element : 15m X-Beam Load Combination 4			
	Job Number : R0076	By : eas		Date: Oct 15
	Document No : 001	Checked : anw		Date: Oct 15

Load Comb. 4 Load at quarter points
10kN load applied at each of the three quarter points

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.208	5.02
	Shear	V_{Rd}	32.91	0.554	59.40
	Tension	$N_{o,Rd}$	90.13	63.86	1.41
	Compression	$N_{b,Rd}$	102.86	164.26	0.63
	Deflection	d	150.00	93.39	1.61
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.57
Vertical	Moment	$M_{c,Rd}$	0.91	0.064	14.17
	Shear	V_{Rd}	47.79	0.169	282.77
	Tension	$N_{o,Rd}$	90.13	4.55	19.81
	Compression	$N_{b,Rd}$	107.35	9.96	10.78
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	6.67
Diagonal	Tension	$N_{o,Rd}$	48.70	14.64	3.33
	Compression	$N_{b,Rd}$	62.76	15.57	4.03
Factor					0.57



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Moment} = \frac{ML}{2}$$

so for ultimate condition

$$W = \frac{1.50 \times 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = \frac{15.00 \times 0.57}{1} = 8.55 \text{ kN}$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= \frac{W_f \times L}{2} \\ &= \frac{(8.55 \times 15)}{2} \\ &= 64.13 \text{ kNm} \end{aligned}$$

and for allowable value

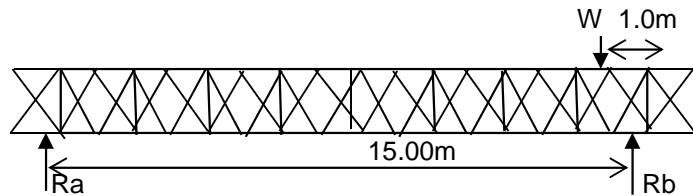
$$\begin{aligned} \text{allowable max moment} &= \frac{64.13}{1.50} \\ &= 42.75 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	64.13 kNm
	Allowable	42.75 kNm

CALCULATION SHEET	Project : Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element : 15m X-Beam Combination 5			
	Job Number : R0076	By : eas	Date: Oct 15	
	Document No : 001	Checked : anw	Date: Oct 15	

Load Comb. 5 Load at END points
10kN load applied at 1.0m distance from the support

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.075	13.91
	Shear	V_{Rd}	32.91	0.22	149.59
	Tension	$N_{o,Rd}$	90.13	8.83	10.21
	Compression	$N_{b,Rd}$	102.86	20.91	4.92
	Deflection	d	150.00	9.79	15.32
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	3.86
Vertical	Moment	$M_{c,Rd}$	0.91	0.025	36.28
	Shear	V_{Rd}	47.79	0.059	809.98
	Tension	$N_{o,Rd}$	90.13	0.18	500.73
	Compression	$N_{b,Rd}$	107.35	7.08	15.16
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	11.43
Diagonal	Tension	$N_{o,Rd}$	48.70	8.83	5.51
	Compression	$N_{b,Rd}$	62.76	9.13	6.87
Factor					3.86



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Shear } R_b = W * 8/9$$

so for ultimate condition

$$W = \frac{1.50 * 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = 15.0 * 3.86 = 57.90 \text{ kN}$$


so maximum shear is as above

$$\begin{aligned} \text{Ultimate } Q_u &= W_f * 14/15 \\ &= (57.90 * 14)/15 \\ &= 54.04 \text{ kN} \end{aligned}$$

and for allowable value

$$\begin{aligned} \text{allowable max shear} &= 54.04/1.50 \\ &= 36.03 \text{ kN} \end{aligned}$$

Shear values	Ultimate	54.04 kN
	Allowable	36.03 kN

CALCULATION SHEET	Project : Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element : 15m X-Beam Results			
	Job Number : R0076	By : eas	Date: Oct 15	
	Document No : 001	Checked : anw	Date: Oct 15	

X-BEAM		
Loadcase	Ultimate	Allowable
No.	Moment	Moment
1 UDL	67.50	45.00
2 Point	67.50	45.00
3 Third	63.00	42.00
4 Quarter	64.13	42.75

Loadcase	Ultimate	Allowable
No.	Shear	Shear
5 End Shear	54.04	36.03

Max Allowable Moment = 42 kNm

Max Allowable Shear = 36 kN

From 15m X-Beam Results with restraint to compression chord at 1.0m c/c:



For simply supported Apollo single X-BEAM TO EUROCODE EN 1999-1

ALAN WHITE DESIGN

Allowable Bending Moment	42 kNm
Allowable Shear	36 kN

Allowable loads for load distributions

Type of Load		Clear span (m)																
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Uniformly Distributed load	kN/m	36.0	24.0	18.0	13.4	9.3	6.9	5.3	4.1	3.4	2.8	2.3	2.0	1.7	1.5	1.3	1.2	1.0
Total UDL	kN	72.0	72.0	72.0	67.2	56.0	48.0	42.0	37.3	33.6	30.5	28.0	25.8	24.0	22.4	21.0	19.8	18.7
Single point load (mid Point)	kN	72.0	56.0	42.0	33.6	28.0	24.0	21.0	18.7	16.8	15.3	14.0	12.9	12.0	11.2	10.5	9.9	9.3
Two point loads (third points)	Each kN	36.0	36.0	31.5	25.2	21.0	18.0	15.8	14.0	12.6	11.5	10.5	9.7	9.0	8.4	7.9	7.4	7.0
Three point loads (quarter points)	Each kN	24.0	24.0	21.0	16.8	14.0	12.0	10.5	9.3	8.4	7.6	7.0	6.5	6.0	5.6	5.3	4.9	4.7

- 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 nodes. All scaffolds and structures should be checked by a qualified structural engineer. Loads indicated in italics and shaded are limited by shear.
 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. Compression chord restraint required at 1m c/c


CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	18m X-Beam Results		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



ALAN WHITE DESIGN

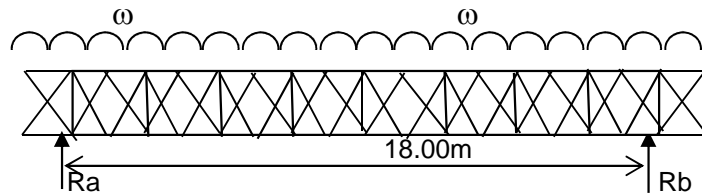
18m X-Beam Results

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	18m X-Beam Load Combination 1		
	Job Number :	R0076	By : eas	Date: Oct 14
	Document No :	001B	Checked : anw	Date: Oct 14


 ALAN WHITE DESIGN

Load Comb. 1 UDL load 10kN/m applied along beam

Element	Action	Formula	Ultimate	Calculated	Factor	
Boom	Moment	$M_{c,Rd}$	1.04	0.97	1.08	
	Shear	V_{Rd}	32.91	6.29	5.23	
	Tension	$N_{o,Rd}$	90.13	288.92	0.31	
	Compression	$N_{b,Rd}$	102.86	864.18	0.12	
	Deflection	d		180.00	703.15	0.26
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$			1.00	0.11
Vertical	Moment	$M_{c,Rd}$	0.91	0.34	2.66	
	Shear	V_{Rd}	47.79	0.87	54.87	
	Tension	$N_{o,Rd}$	90.13	7.83	11.52	
	Compression	$N_{b,Rd}$	107.35	62.73	1.71	
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$			1.00	1.13
Diagonal	Tension	$N_{o,Rd}$	48.70	77.03	0.63	
	Compression	$N_{b,Rd}$	62.76	90.78	0.69	
Factor					0.11	



$$\text{Max Moment} = \frac{ML^2}{8}$$

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

$$W = \frac{1.5 \times 10 \times 18}{2} = 15.00 \text{ kN}$$

apply factor from above

$$W_f = \frac{15 \times 0.11}{1} = 1.65 \text{ kN}$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= \frac{W_f \times 18^2}{8} \\ &= \frac{1.65 \times 18^2}{8} \\ &= 66.83 \text{ kNm} \end{aligned}$$

and for allowable value

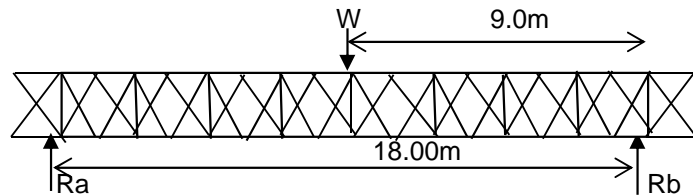
$$\begin{aligned} \text{allowable max moment} &= \frac{66.83}{1.50} \\ &= 44.55 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	66.83 kNm
	Allowable	44.55 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	18m X-Beam Load Combination 2			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb. 2 Point load 10kN load applied at midspan of beam

Element	Action	Formula	Ultimate	Calculated	Factor	
Boom	Moment	$M_{c,Rd}$	1.04	0.139	7.50	
	Shear	V_{Rd}	32.91	0.309	106.50	
	Tension	$N_{o,Rd}$	90.13	47.72	1.89	
	Compression	$N_{b,Rd}$	102.86	99.18	1.04	
	Deflection	d		180.00	71.34	2.52
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$			1.00	0.94
Vertical	Moment	$M_{c,Rd}$	0.91	0.028	32.40	
	Shear	V_{Rd}	47.79	0.061	783.42	
	Tension	$N_{o,Rd}$	90.13	0.75	120.18	
	Compression	$N_{b,Rd}$	107.35	5.72	18.77	
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$			1.00	12.85
Diagonal	Tension	$N_{o,Rd}$	48.70	5.26	9.26	
	Compression	$N_{b,Rd}$	62.76	5.73	10.95	
			Factor		0.94	



$$\text{Max Moment} = \frac{ML}{4}$$

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

$$W = 1.50 * 10$$

$$= 15.00 \text{ kN}$$

apply factor from above

$$W_f = 15 * .94$$

$$= 14.10 \text{ kN}$$

so maximum moment is as above

$$\text{Ultimate } M_u = \frac{W_f * L}{4}$$

$$= \frac{14.10 * 18}{4}$$

$$= 63.45 \text{ kNm}$$

and for allowable value

$$\text{allowable max moment} = \frac{63.45}{1.50}$$

$$= 42.30 \text{ kNm}$$

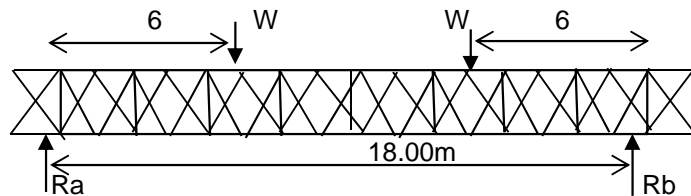
Moment values	Ultimate	63.45 kNm
	Allowable	42.30 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	18m X-Beam Load Combination 3		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



Load Comb. 3 PL at third points 10kN load applied at each of the two third points

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.19	5.46
	Shear	V_{Rd}	32.91	0.47	70.02
	Tension	$N_{o,Rd}$	90.13	44.73	2.02
	Compression	$N_{b,Rd}$	102.86	134.14	0.77
	Deflection	d	180.00	113.62	1.58
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.69
Vertical	Moment	$M_{c,Rd}$	0.91	0.05	18.51
	Shear	V_{Rd}	47.79	0.12	415.56
	Tension	$N_{o,Rd}$	90.13	1.28	70.42
	Compression	$N_{b,Rd}$	107.35	6.72	15.97
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	9.38
Diagonal	Tension	$N_{o,Rd}$	48.70	9.97	4.88
	Compression	$N_{b,Rd}$	62.76	10.75	5.84
			Factor		0.69



Loads indicated in italics and shaded are limited by shear.
 Max Moment= $ML/3$

so for ultimate condition

$$W = \frac{1.50 \cdot 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = 15.00 \cdot 0.69 = 10.35 \text{ kN}$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= W_f \cdot L / 3 \\ &= (10.35 \cdot 18) / 3 \\ &= 62.10 \text{ kNm} \end{aligned}$$

and for allowable value

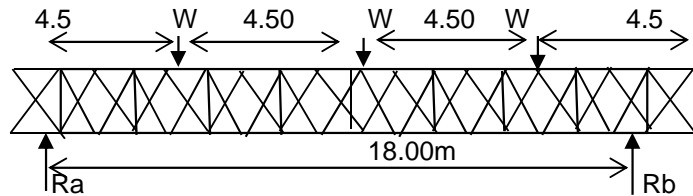
$$\begin{aligned} \text{allowable max moment} &= 62.10 / 1.50 \\ &= 41.40 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	62.10 kNm
	Allowable	41.40 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	18m X-Beam Load Combination 4			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb. 4 Load at quarter points
10kN load applied at each of the three quarter points

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.245	4.26
	Shear	V_{Rd}	32.91	0.566	58.14
	Tension	$N_{o,Rd}$	90.13	71.42	1.26
	Compression	$N_{b,Rd}$	102.86	195.02	0.53
	Deflection	d	180.00	155.21	1.16
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.48
Vertical	Moment	$M_{c,Rd}$	0.91	0.074	12.26
	Shear	V_{Rd}	47.79	0.186	256.93
	Tension	$N_{o,Rd}$	90.13	4.87	18.51
	Compression	$N_{b,Rd}$	107.35	9.9	10.84
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	6.30
Diagonal	Tension	$N_{o,Rd}$	48.70	14.69	3.31
	Compression	$N_{b,Rd}$	62.76	18.86	3.33
Factor					0.48



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Moment} = \frac{ML}{2}$$

so for ultimate condition

$$W = \frac{1.50 \times 10}{15.00} \text{ kN}$$

apply factor from above

$$W_f = 15.00 \times 0.48 = 7.20 \text{ kN}$$


so maximum moment is as above

$$\begin{aligned} \text{Ultimate } M_u &= \frac{W_f \times L}{2} \\ &= \frac{(7.20 \times 18)}{2} \\ &= 64.80 \text{ kNm} \end{aligned}$$

and for allowable value

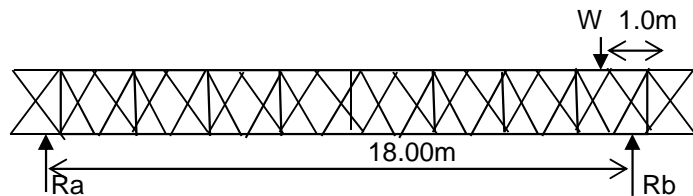
$$\begin{aligned} \text{allowable max moment} &= \frac{64.80}{1.50} \\ &= 43.20 \text{ kNm} \end{aligned}$$

Moment values	Ultimate	64.80 kNm
	Allowable	43.20 kNm

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode			 ALAN WHITE DESIGN
	Element :	18m X-beam Load Combination 5			
	Job Number :	R0076	By : eas	Date: Oct 14	
	Document No :	001B	Checked : anw	Date: Oct 14	

Load Comb. 5 End Shear 10kN load applied at a 1.0m distance from the support

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	1.04	0.077	13.55
	Shear	V_{Rd}	32.91	0.227	144.97
	Tension	$N_{o,Rd}$	90.13	7.51	12.00
	Compression	$N_{b,Rd}$	102.86	21.73	4.73
	Deflection	d	180.00	15.72	11.45
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	3.72
Vertical	Moment	$M_{c,Rd}$	0.91	0.007	129.59
	Shear	V_{Rd}	47.79	0.013	3676.07
	Tension	$N_{o,Rd}$	90.13	0.2	450.66
	Compression	$N_{b,Rd}$	107.35	0.77	139.41
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	73.77
Diagonal	Tension	$N_{o,Rd}$	48.70	6.11	7.97
	Compression	$N_{b,Rd}$	62.76	6.36	9.87
Factor					3.72



Loads indicated in italics and shaded are limited by shear.

$$\text{Max Shear } R_b = W * 8/9$$

so for ultimate condition

$$W = \frac{15.0 * 10.0}{15.00} \text{ kN}$$

apply factor from above

$$W_f = \frac{15.00 * 3.72}{1} = 55.80 \text{ kN}$$

so maximum shear is as above

$$\begin{aligned} \text{Ultimate } Q_u &= \frac{W_f * 17}{18} \\ &= \frac{55.80 * 17}{18} \\ &= 52.70 \text{ kN} \end{aligned}$$

and for allowable value

$$\begin{aligned} \text{allowable max shear} &= \frac{52.70}{1.50} \\ &= 35.13 \text{ kN} \end{aligned}$$

Shear values	Ultimate	52.70 kN
	Allowable	35.13 kN

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	18m X-Beam Results		
	Job Number :	R0076	By : eas	Date:Oct 14
	Document No :	001B	Checked :anw	Date:Oct 14



ALAN WHITE DESIGN

X-BEAM		
Loadcase	Ultimate	Allowable
No.	Moment	Moment
1 UDL	66.83	44.55
2 Point	63.45	42.30
3 Third	62.10	41.40
4 Quarter	64.80	43.20

Loadcase	Ultimate	Allowable
No.	Shear	Shear
5 End Shear	52.70	35.13

Max Allowable Moment = 41 kNm

Max Allowable Shear = 35 kN

From 18m X-Beam Results with restraint to compression chord at 1.0m c/c:

For simply supported Apollo single X-BEAM TO EUROCODE EN 1999-1



ALAN WHITE DESIGN

Allowable Bending Moment	41 kNm
Allowable Shear	35 kN

Allowable loads for load distributions

Type of Load		Clear span (m)																
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Uniformly Distributed load	kN/m	<i>35.0</i>	<i>23.3</i>	<i>17.5</i>	13.1	9.1	6.7	5.1	4.0	3.3	2.7	2.3	1.9	1.7	1.5	1.3	1.1	1.0
Total UDL	kN	<i>70.0</i>	<i>70.0</i>	<i>70.0</i>	65.6	54.7	46.9	41.0	36.4	32.8	29.8	27.3	25.2	23.4	21.9	20.5	19.3	18.2
Single point load (mid Point)	kN	<i>70.0</i>	54.7	41.0	32.8	27.3	23.4	20.5	18.2	16.4	14.9	13.7	12.6	11.7	10.9	10.3	9.6	9.1
Two point loads (third points)	Each kN	<i>35.0</i>	<i>35.0</i>	30.8	24.6	20.5	17.6	15.4	13.7	12.3	11.2	10.3	9.5	8.8	8.2	7.7	7.2	6.8
Three point loads (quarter points)	Each kN	<i>23.3</i>	<i>23.3</i>	20.5	16.4	13.7	11.7	10.3	9.1	8.2	7.5	6.8	6.3	5.9	5.5	5.1	4.8	4.6

- 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 nodes. All scaffolds and structures should be checked by a qualified structural engineer. Loads indicated in italics and shaded are limited by shear.
 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. Compression chord restraint required at 1m c/c

CALCULATION SHEET	Project :	Apollo X-beam to Eurocode		
	Element :	Overall X-Beam Results		
	Job Number :	R0076	By : eas	Date: Oct 14
	Document No :	001B	Checked :anw	Date: Oct 14



ALAN WHITE DESIGN

Overall X-Beam Results

Overall Graded Results for Allowable Working Loads on an X-Beam



ALAN WHITE DESIGN

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

Test Results

	Span(m)					
	3	6	9	12	15	18
Allowable Moment	37	37	41	41	42	41
Allowable Shear (Load on Vertical)	44	39	37	37	36	35

Extrapolated Allowable loads for load distributions

Type of Load		Clear span (m)																
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Uniformly Distributed load	kN/m	44.0	29.3	18.5	11.8	8.2	6.0	5.1	4.0	3.3	2.7	2.3	1.9	1.7	1.5	1.3	1.1	1.0
Total UDL	kN	88.0	88.0	74.0	59.2	49.3	42.3	41.0	36.4	32.8	29.8	27.3	25.2	24.0	22.4	21.0	19.3	18.2
Single point load (mid Point)	kN	74.0	49.3	37.0	29.6	24.7	21.1	20.5	18.2	16.4	14.9	13.7	12.6	12.0	11.2	10.5	9.6	9.1
Two point loads (third points)	Each kN	44.0	37.0	27.8	22.2	18.5	15.9	15.4	13.7	12.3	11.2	10.3	9.5	9.0	8.4	7.9	7.2	6.8
Three point loads (quarter points)	Each kN	29.3	24.7	18.5	14.8	12.3	10.6	10.3	9.1	8.2	7.5	6.8	6.3	6.0	5.6	5.3	4.8	4.6

- 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 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. Compression chord restraint required at 1m c/c
 4. Factor of Safety = 1.65
 5. Calculations as per BS EN 1999-1-1

