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

Alan N White B.Sc., M.Eng., C.Eng., M.I.C.E., M.I.H.T.

OCT 2014

Somerset House
11 Somerset Place
GLASGOW G3 7JT
Tel:0141 354 6579
Fax:0141 354 6549

DESIGN REPORT

TABLE OF CONTENTS

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.

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.

ALAN WHITE DESIGN

CALCULATIONS

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

ALAN WHITE DESIGN

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

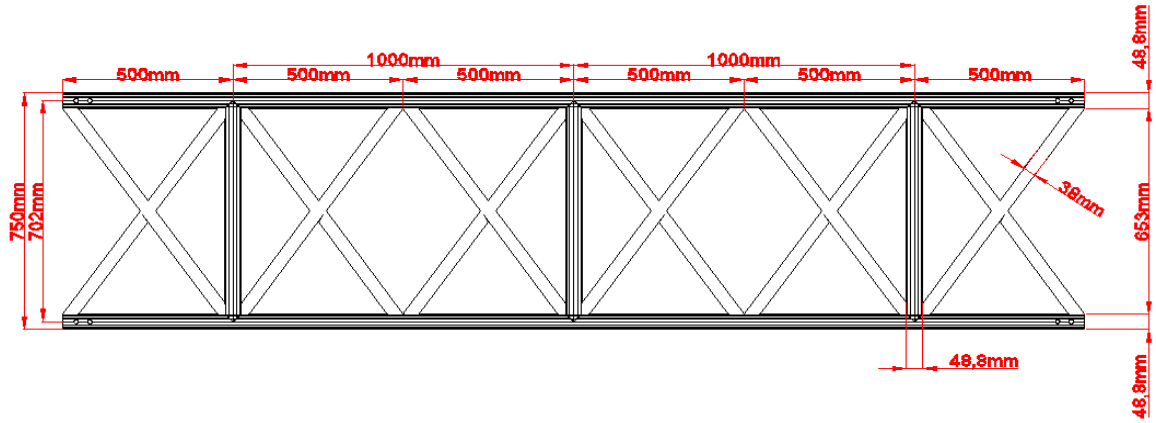
The alloy used is 6082 T6:

f_o= 250 N/mm^2

f_u= 290 N/mm^2

Layout

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



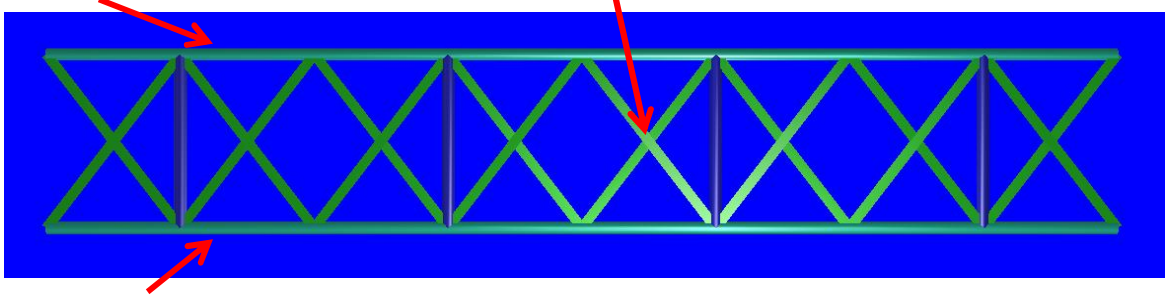
Design

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)

Top Boom Alu Scaffold Tube Diagonal RHS

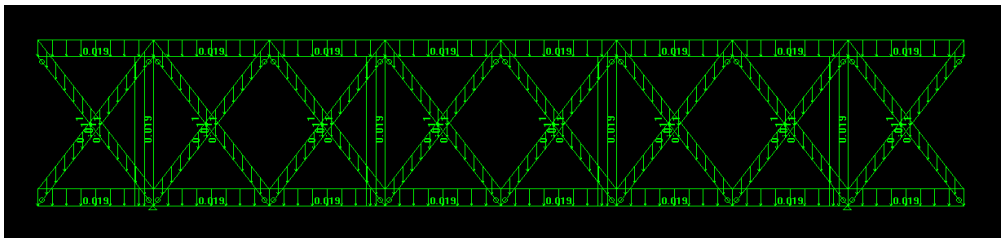


Bottom Boom Alu Scaffold Tube

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

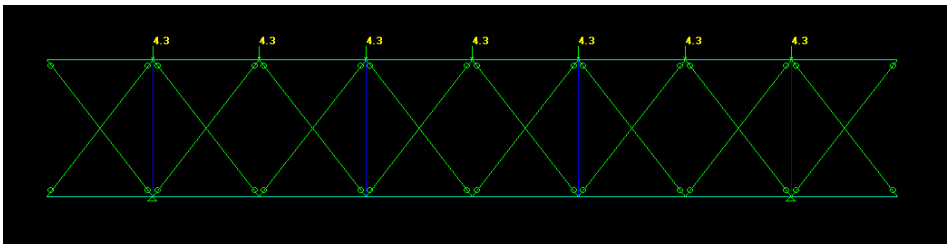
Load Case 1 Self Weight

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



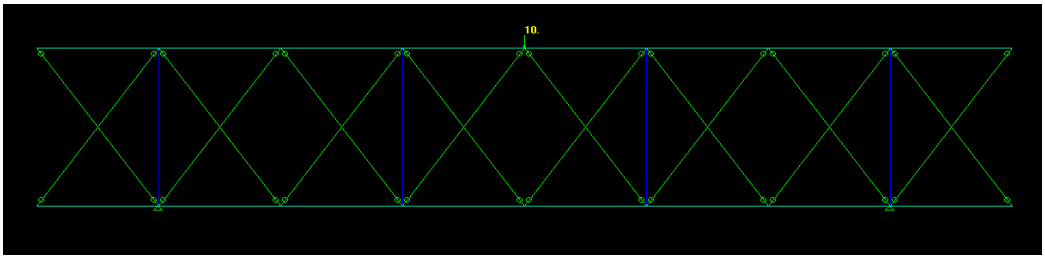
Load Case 2 UDL

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



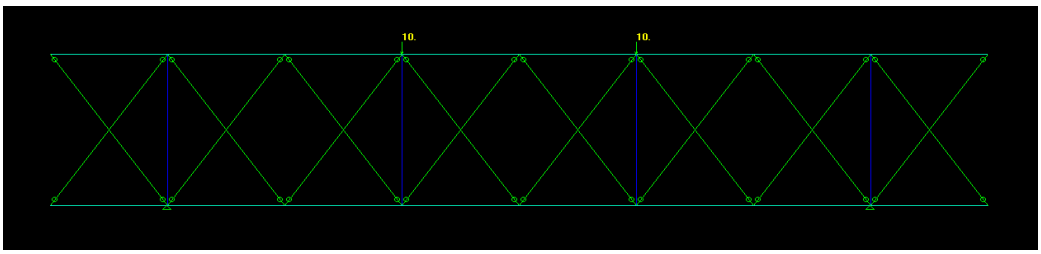
Load Case 3 Central Point Load

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



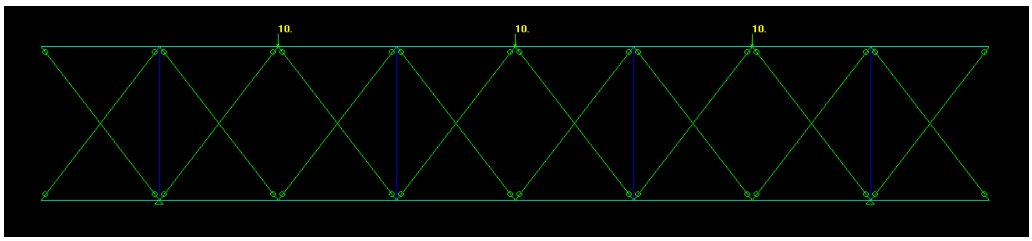
Load Case 4 Two Point Loads

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



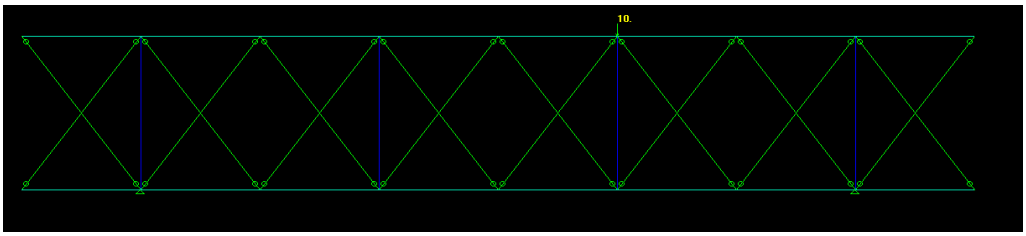
Load Case 5 Three Point Loads

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

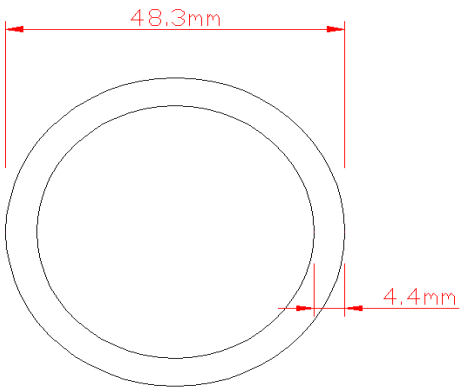
Above Combinations were checked for the following design factors:

γ_D= 1.25

γ_L= 1.50

CHS Boom Layout

Boom 48.3 x 4.4 CHS



Section Properties

A=	607	mm^2	
I=	147654	mm^4	
W_{el}=	6114	mm^3	
W_{pl}=	8254	mm^3	
ry=	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	

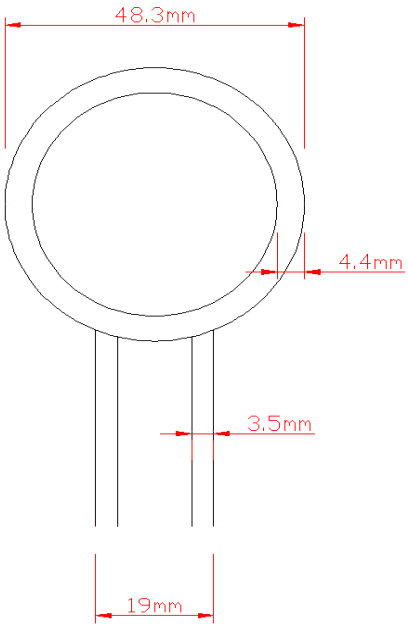
Class A, without welds, Internal parts

β_1=	11ε
=	11*1.0
=	11.00
>	10.98

Section is class 1

Boom 48.3 x 4.4 CHS HAZ

There is a HAZ at welded joint to the diagonal brace



t_{boom}= 4.40mm

$t_{diagonal}$= 3.5mm

$t_{average}$= 3.95mm

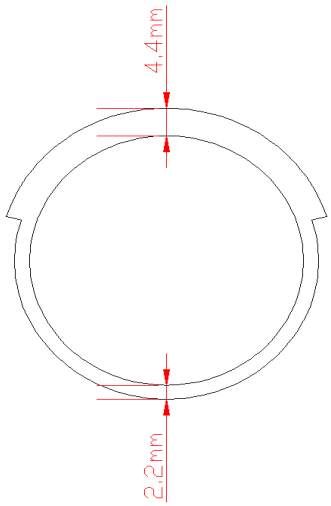
All welds are TIG.
As per EN 1999-1-1 6.1.6.3

b_{haz} = 30mm

Therefore HAZ extends 30mm from intersection of welded materials

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
ry=	14.7	mm

Truss Boom Moment Capacity (6.2.5.1)

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

α =	W_{pl}/W_{el}	(Table 6.4)
=	1.35	
W_{el} =	3.40	cm^3
f_o =	250	N/mm^2
γ_{M1} =	1.1	(6.1.3)

= 1.35*3.40*250/1100

$M_{c,Rd}$ = 1.04 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
γ_{M1}=	1.1	
f_o =	250	N/mm^2

= 250.80*250/(SQRT(3)*1100)

V_{Rd} = 32.91 kN

Truss Boom Axial Comp Capacity @ 1000mm (effective length of beam between restraints)

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

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

E = 70,000 N/mm^2
I = 147,654 mm^4
k = 0.50 (Table I.2)
L = 1,000 mm

N_{cr} = ((PI()^2)*70000*147654)/((0.5^2)*(1000^2))
= 408,040.24 N

$\lambda = \sqrt{A_{eff} f_o / N_{cr}}$ (6.3.1.2)
= 0.61 A_{eff} = 607 mm^2

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

$\Phi = 0.5(1+\acute{\alpha}(\lambda-\lambda_o)+\lambda^{\curlywedge})$
$\acute{\alpha}$ = 0.20 Table 6.6
λ_o = 0.10 Table 6.6
Φ = 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 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 kN

Truss Boom Axial Tension Capacity (6.2.3)

1. General yielding

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

$f_o = 250 N/mm^2$

$A_g = 607 mm^2$

$\gamma_{M1} = 1.1$

$= 607*250/1100$

$= 137.95$ kN

2. Local failure

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

$f_u = 290 N/mm^2$

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

$= 0.64*607 mm^2$

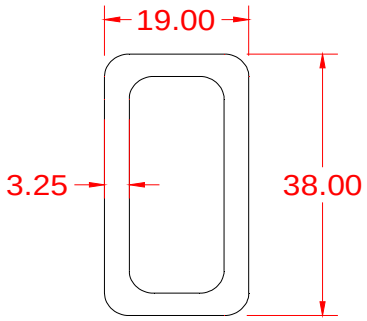
$= 388.5 mm^2$

$\gamma_{M1} = 1.25$

$= 388.5*290/1250$

$= 90.13$ kN

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	
ry=	7.0	mm	

for slenderness

β= b/t b= 38-2*3.25
= 31.50
= 9.69 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 x A_{eff} f_o /γ_{M1} (6.3.1.1)

N_{cr} = π^2 EI / k^2 L^2 (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 N

λ = $\sqrt{A_{eff}}$ f_o / N_{cr} (6.3.1.2)
= 0.30 A_{eff} = 328 mm^2

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

$\Phi = 0.5(1+\acute{\alpha}(\lambda-\lambda_o)+\lambda^{\curvearrowleft})$

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

$\lambda_o =$ 0.10 Table 6.6

$\Phi =$ 0.56

$X =$ 0.89

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

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

$= 328-126.4*(1-0.5)$

$=$ 264.80 mm^2

$k =$ 0.946

$N_{b,Rd} = 0.946*0.89*328*250/1100$

$=$ 62.76 kN

Diagonal Axial Tension Capacity (6.2.3)

1. General yielding

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

$f_o = 250N/mm^2$

$A_g = 328mm^2$

$\gamma_{M1} = 1.1$

$= 328*250/1100$

$=$ 79.55 kN

2. Local failure

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

$f_u = 290N/mm^2$

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

$= 0.64*328mm^2$

$= 209.9mm^2$

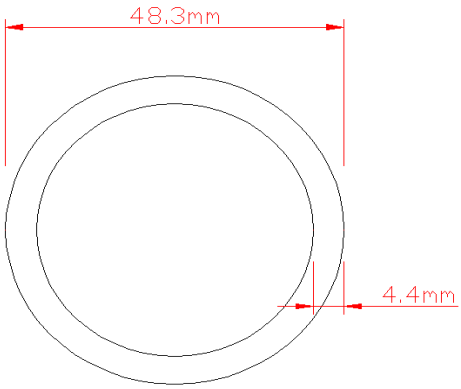
$\gamma_{M1} = 1.25$

$= 209.9*290/1250$

$=$ 48.70 kN

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	
ry=	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=	11ε
=	11*1.0
=	11.00
>	10.98

Section is class 1

Vertical CHS Moment Capacity (6.2.5.1)

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

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

$= 1.35$

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

$f_o = 250\ N/mm^2$

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

$= 1.35*6.11*250/1100$

$M_{c,Rd} = 1.87$ kNm

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

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

$= 6.11*0.64$

$= 3.91\ cm^3$

$f_u = 290\ N/mm^2$

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

$= 3.91*290/1250$

$M_{u,Rd} = 0.91$ kNm

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

Vertical CHS Shear Capacity (6.2.6)

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

$Av = 0.6A$

$Av = 0.6*607$

$Av = 364.20\ mm^2$

$\gamma_{M1} = 1.1$

$f_o = 250\ N/mm^2$

$= 364.20*250/(SQRT(3)*1100)$

$V_{Rd} = 47.79$ kN

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

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

$k = \omega_x$

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

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

$= 0.65$

$k = 0.65$

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

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

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

$k = 0.50$

$L = 750$ mm

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

$= 725{,}404.87$ N

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

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

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

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

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

$\lambda_o = 0.10$ Table 6.6

$\Phi = 0.64$

$X = 0.79$

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

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

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

$= 455.50\ mm^2$

$k = 0.985$

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

$= 107.35\ kN$

Vertical CHS Axial Tension Capacity (6.2.3)

1. General yielding

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

$f_o = 250N/mm^2$

$A_g = 607mm^2$

$\gamma_{M1} = 1.1$

$= 607*250/1100$

$= 137.95\ kN$

2. Local failure

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

$f_u = 290N/mm^2$

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

$= 607*0.64$

$= 388.5mm^2$

$\gamma_{M1} = 1.25$

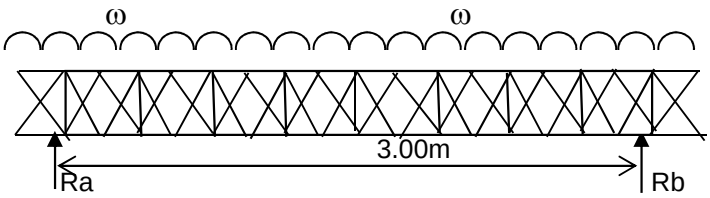
$= 388.5*290/1250$

$= 90.13\ kN$

3m X-Beam Results

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**



Max Moment= $ML^2/8$

so for ultimate condition

W= 1.5*10
15.00 kN

apply factor from above

Wf= 15*4.33
= 64.95 kN

so maximum moment is as above

Ultimate Mu= Wf*3^2/8
= (64.95*3^2)/8
= 73.07 kNm

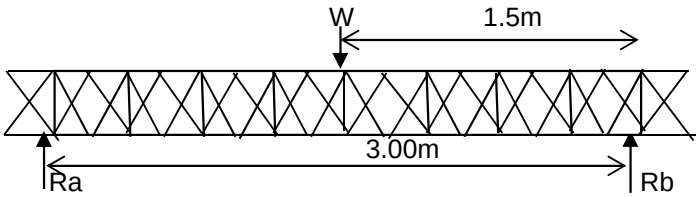
and for allowable value

allowable max moment= 73.07/1.50
= 48.71 kNm

Moment values	**Ultimate**	**73.07 kNm**
	Allowable	**48.71 kNm**

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**



Max Moment= ML/4

so for ultimate condition

W= 1.50*10
= 15.00 kN

apply factor from above

Wf= 15*5.82
= 87.30 kN

so maximum moment is as above

Ultimate Mu= Wf*3/4
= 87.3*3/4
= 65.48 kNm

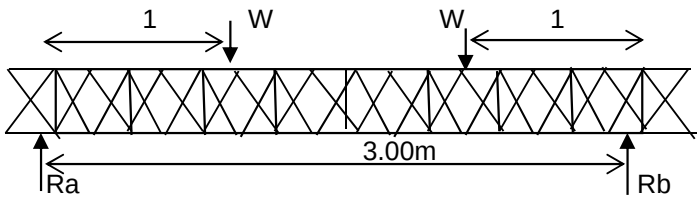
and for allowable value

allowable max moment= 65.48/1.50
= 43.65 kNm

Moment values	**Ultimate**	**65.48 kNm**
	Allowable	**43.65 kNm**

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*10
15.00 kN

apply factor from above

Wf= 15*3.70
= 55.50 kN

so maximum moment is as above

Ultimate Mu= Wf*3/3
= (55.5*3)/3
= 55.50 kNm

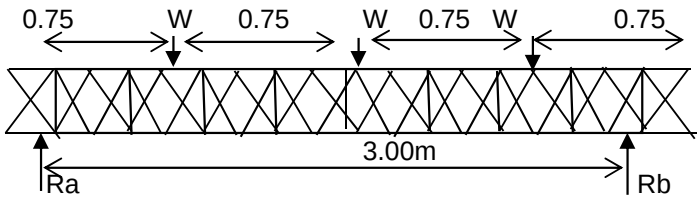
and for allowable value

allowable max moment= 55.5/1.50
= 37.00 kNm

Moment values	**Ultimate**	**55.50 kNm**
	Allowable	**37.00 kNm**

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*10
15.00 kN

apply factor from above

Wf= 15*3.28
= 49.20 kN

so maximum moment is as above

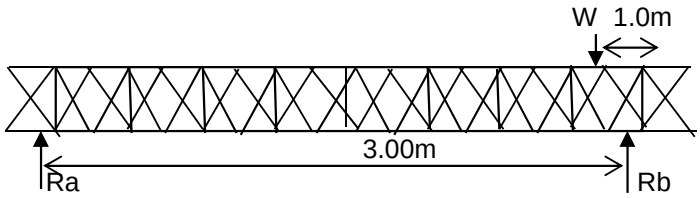
Ultimate Mu= Wf*L/2
= (49.2*3/2)
= 73.80 kNm

allowable max moment= 73.8/1.5
= 49.20 kNm

Moment values	**Ultimate**	**73.80 kNm**
	Allowable	**49.20 kNm**

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	7.85
	Compression	$N_{b,Rd}$	62.76	6.34	9.90
				Factor	**6.73**



Max Shear Rb= W*2/3

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15*6.73
= 100.95 kN

so maximum shear is as above

Ultimate Qu= Wf*2/3
= (100.95*2)/3
= 67.30 kN

and for allowable value

allowable max shear= 67.30/1.50
= 44.87 kN

Shear values	**Ultimate**	**67.30 kN**
	Allowable	**44.87 kN**

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	*44.0*	*29.3*	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	*88*	*88.0*	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	*44.0*	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	*29.3*	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

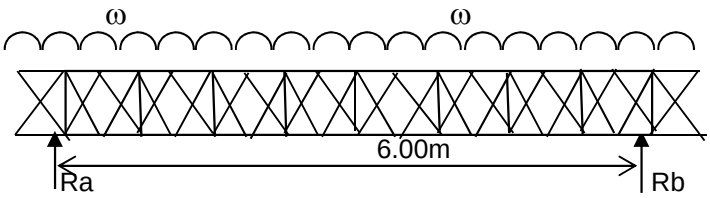
Notes:

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

6m X-Beam Results

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**



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*0.83
= 12.45 kN

so maximum moment is as above

Ultimate Mu= $Wf*L^2/8$
= (12.45*6^2)/8
= 56.03 kNm

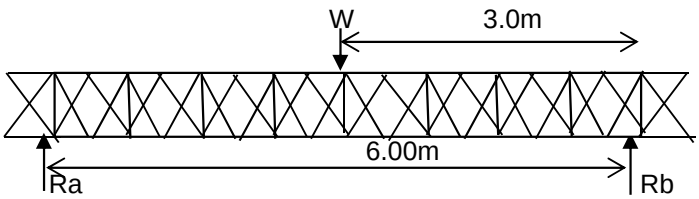
and for allowable value

allowable max moment= 56.03/1.50
= 37.35 kNm

Moment values	**Ultimate**	**56.03 kNm**
	Allowable	**37.35 kNm**

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 kN

apply factor from above

Wf= 15*2.94
= 44.10 kN

so maximum moment is as above

Ultimate Mu= Wf*L/4
= 44.10*6/4
= 66.15 kNm

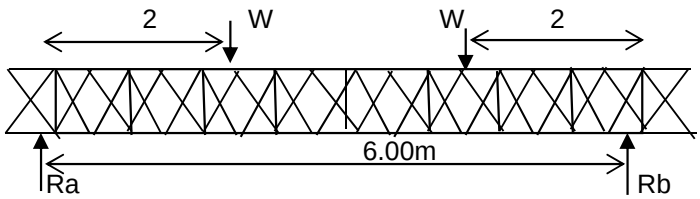
and for allowable value

allowable max moment= 66.15/1.50
= 44.10 kNm

Moment values	**Ultimate**	**66.15 kNm**
	Allowable	**44.10 kNm**

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.

Max Moment= ML/3

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15.00*2.03
= 30.45 kN

so maximum moment is as above

Ultimate Mu= Wf*L/3
= (30.45*6)/3
= 60.90 kNm

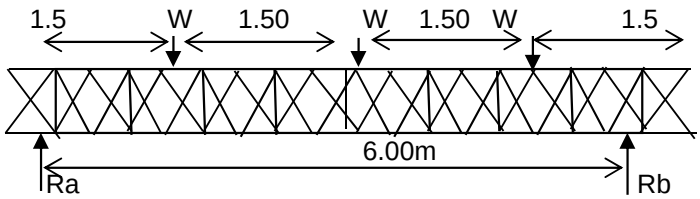
and for allowable value

allowable max moment= 60.9/1.50
= 40.60 kNm

Moment values	**Ultimate**	**60.90 kNm**
	Allowable	**40.60 kNm**

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.

Max Moment= ML/2

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15.00*1.49
= 22.35 kN

so maximum moment is as above

Ultimate Mu= Wf*L/2
= (22.35*6)/2
= 67.05 kNm

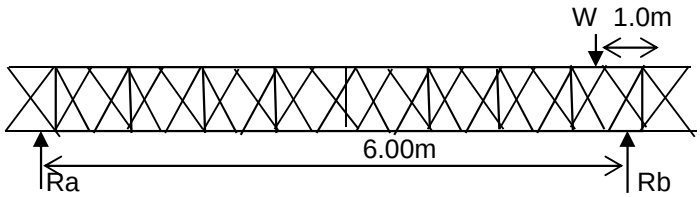
and for allowable value

allowable max moment= 67.05/1.50
= 44.70 kNm

Moment values	**Ultimate**	**67.05 kNn**
	Allowable	**44.70 kNm**

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.

Max Shear Rb= W*5/6

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15.0*4.77
= 71.55 kN

so maximum shear is as above

Ultimate Qu= Wf*5/6
= (71.55*5)/6
= 59.63 kN

and for allowable value

allowable max shear= 59.63/1.50
= 39.75 kN

Shear values	**Ultimate**	**59.63 kN**
	Allowable	**39.75 kN**

X-BEAM

Loadcase No.		Ultimate Moment	Allowable 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 No.		Ultimate Shear	Allowable 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:

ALAN WHITE DESIGN

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	*39.0*	*26.0*	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	*78.0*	*78.0*	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	*39.0*	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	*26.0*	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

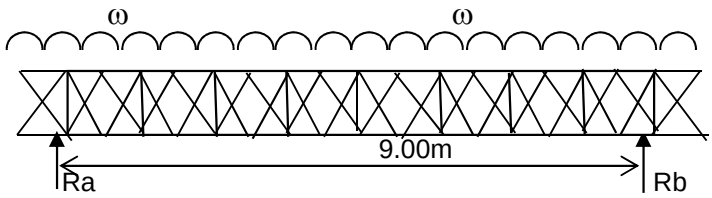
Notes:

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

9m X-Beam Results

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 kN

so maximum moment is as above

Ultimate Mu= Wf*9^2/8
= (6.3*9^2)/8
= 63.79 kNm

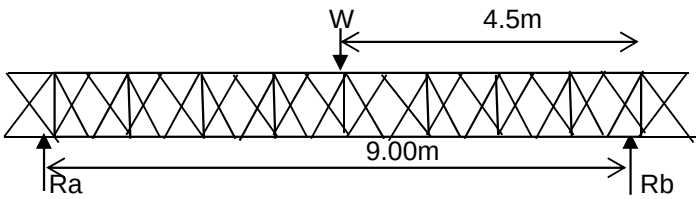
and for allowable value

allowable max moment= 63.79/1.50
= 42.53 kNm

Moment values	**Ultimate**	**63.79 kNm**
	Allowable	**42.53 kNm**

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**



Max Moment= ML/4

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

W= 1.50*10
= 15.00 kN

apply factor from above

Wf= 15*2.32
= 34.80 kN

so maximum moment is as above

Ultimate Mu= Wf*9/4
= 34.8*9/4
= 78.30 kNm

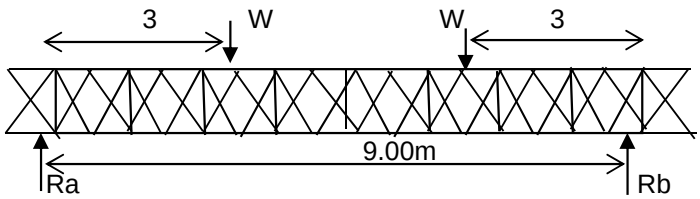
and for allowable value

allowable max moment= 78.30/1.50
= 52.20 kNm

Moment values	**Ultimate**	**78.30 kNm**
	Allowable	**52.20 kNm**

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.

Max Moment= ML/3

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15.00*1.38
= 20.70 kN

so maximum moment is as above

Ultimate Mu= Wf*9/3
= (20.70*9)/3
= 62.10 kNm

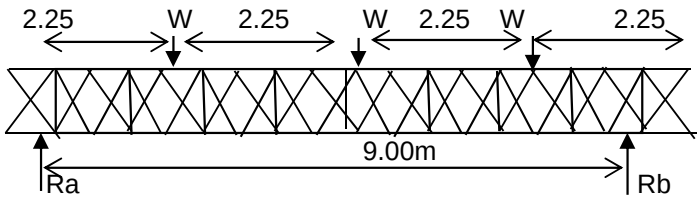
and for allowable value

allowable max moment= 62.10/1.50
= 41.40 kNm

Moment values	**Ultimate**	**62.10 kNm**
	Allowable	**41.40 kNm**

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.

Max Moment= ML/2

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15.00*1.06
= 15.90 kN

so maximum moment is as above

Ultimate Mu= Wf*9/2
= (15.90*9)/2
= 71.55 kNm

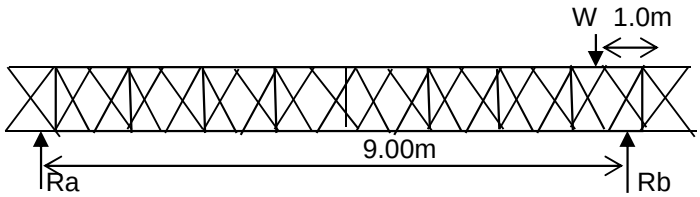
and for allowable value

allowable max moment= 71.55/1.50
= 47.70 kNm

Moment values	**Ultimate**	**71.55 kNm**
	Allowable	**47.70 kNm**

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.

Max Shear Rb= W*8/9

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15.00*4.26
= 63.90 kN

so maximum shear is as above

Ultimate Qu= Wf*8/9
= (63.9*8)/9
= 56.80 kN

and for allowable value

allowable max shear= 56.80/1.50
= 37.87 kN

Shear values	**Ultimate**	**56.80 kN**
	Allowable	**37.87 kN**

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:

ALAN WHITE DESIGN

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

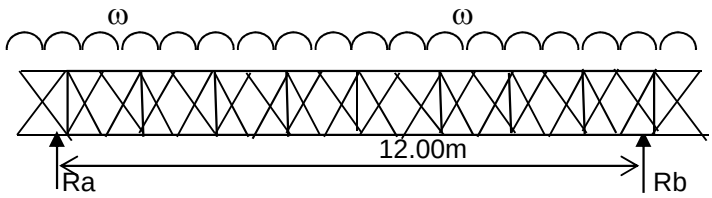
Notes

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.

12m X-Beam Results

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**



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*0.24
= 3.60 kN

so maximum moment is as above

Ultimate Mu= Wf*12^2/8
= (3.6*12^2)/8
= 64.80 kNm

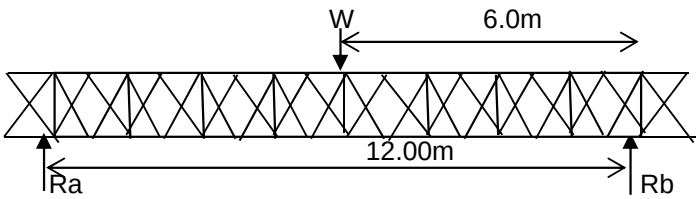
and for allowable value

allowable max moment= 64.80/1.50
= 43.20 kNm

Moment values	**Ultimate**	**64.80 kNm**
	Allowable	**43.20 kNm**

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**



Max Moment= ML/4

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

W= 1.50*10
= 15.00 kN

apply factor from above

Wf= 15*1.44
= 21.60 kN

so maximum moment is as above

Ultimate Mu= Wf*L/4
= 21.6*12/4
= 64.80 kNm

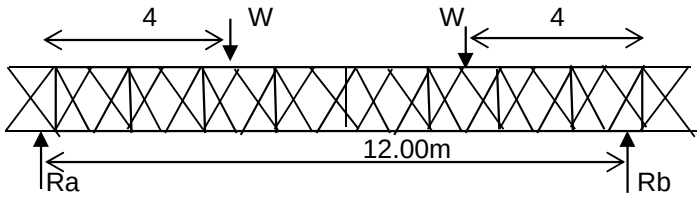
and for allowable value

allowable max moment= 64.80/1.50
= 43.20 kNm

Moment values	**Ultimate**	**64.80 kNm**
	Allowable	**43.20 kNm**

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.

Max Moment= ML/3

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15.00*1.04
= 15.60 kN

so maximum moment is as above

Ultimate Mu= Wf*L/3
= (15.60*12)/3
= 62.40 kNm

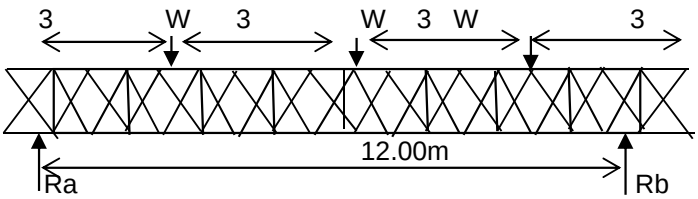
and for allowable value

allowable max moment= 62.40/1.50
= 41.60 kNm

Moment values	**Ultimate**	**62.40 kNm**
	Allowable	**41.60 kNm**

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.

Max Moment= ML/2

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15.00*0.73
= 10.95 kN

so maximum moment is as above

Ultimate Mu= Wf*12/2
= (10.95*12)/2
= 65.70 kNm

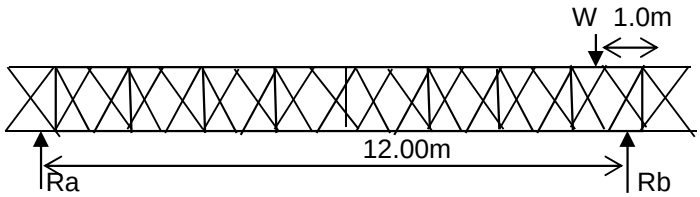
and for allowable value

allowable max moment= 65.70/1.50
= 43.80 kNm

Moment values	**Ultimate**	**65.70 kNm**
	Allowable	**43.80 kNm**

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.

Max Shear Rb= W*8/9

so for ultimate condition

W= 1.50*10

15.00 kN

apply factor from above

Wf= 15.0*4.04

= 60.60 kN

so maximum shear is as above

Ultimate Qu= Wf*11/12

= (60.6*11)/12

= 55.55 kN

and for allowable value

allowable max shear= 55.55/1.50

= 37.03 kN

Shear values	**Ultimate**	**55.55 kN**
	Allowable	**37.03 kN**

X-BEAM

Loadcase No.		Ultimate Moment	Allowable 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 No.		Ultimate Shear	Allowable 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:

ALAN WHITE DESIGN

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

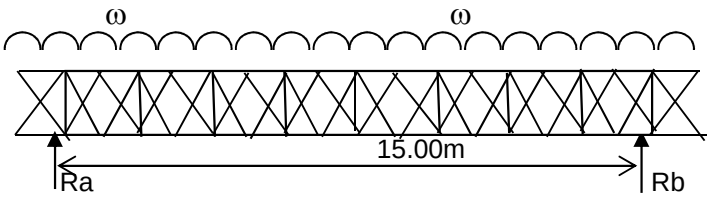
Notes:

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 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

15m X-Beam Results

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**



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*0.16
= 2.40 kN

so maximum moment is as above

Ultimate Mu= Wf*15^2/8
= (2.40*15^2)/8
= 67.50 kNm

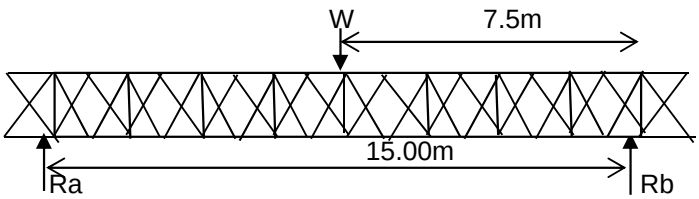
and for allowable value

allowable max moment= 67.50/1.50
= 45.00 kNm

Moment values	**Ultimate**	**67.50 kNm**
	Allowable	**45.00 kNm**

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*10
= 15.00 kN

apply factor from above

Wf= 15*1.20
= 18.00 kN

so maximum moment is as above

Ultimate Mu= Wf*15/4
= 18.00*15/4
= 67.50 kNm

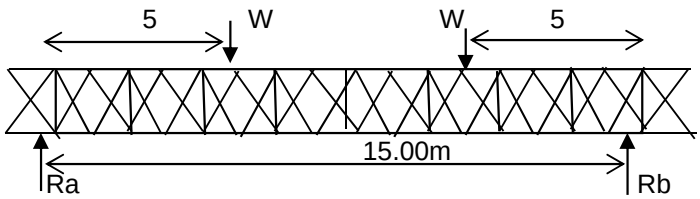
and for allowable value

allowable max moment= 67.50/1.50
= 45.00 kNm

Moment values	**Ultimate**	**67.50 kNm**
	Allowable	**45.00 kNm**

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.

Max Moment= ML/3

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15.00*0.84
= 12.60 kN

so maximum moment is as above

Ultimate Mu= Wf*L/3
= (12.60*15)/3
= 63.00 kNm

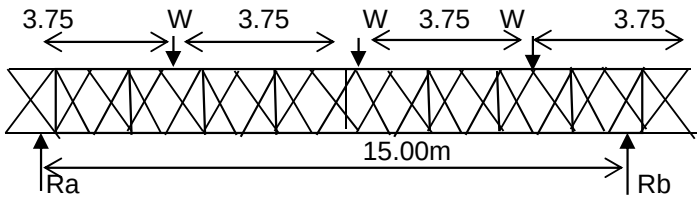
and for allowable value

allowable max moment= 63.00/1.50
= 42.00 kNm

Moment values	**Ultimate**	**63.00 kNm**
	Allowable	**42.00 kNm**

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.

Max Moment= ML/2

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15.00*0.57
= 8.55 kN

so maximum moment is as above

Ultimate Mu= Wf*L/2
= (8.55*15)/2
= 64.13 kNm

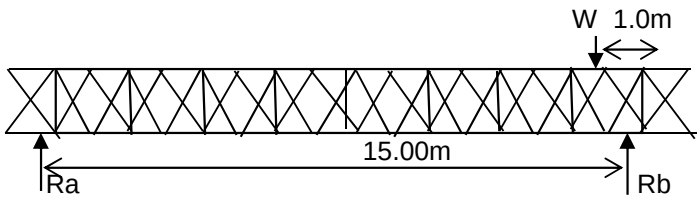
and for allowable value

allowable max moment= 64.13/1.50
= 42.75 kNm

Moment values	**Ultimate**	**64.13 kNm**
	Allowable	**42.75 kNm**

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.

Max Shear Rb= W*8/9

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15.0*3.86
= 57.90 kN

so maximum shear is as above

Ultimate Qu= Wf*14/15
= (57.90*14)/15
= 54.04 kN

and for allowable value

allowable max shear= 54.04/1.50
= 36.03 kN

Shear values	**Ultimate**	**54.04 kN**
	Allowable	**36.03 kN**

X-BEAM

Loadcase No.		Ultimate Moment	Allowable 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 No.		Ultimate Shear	Allowable 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:

ALAN WHITE DESIGN

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

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

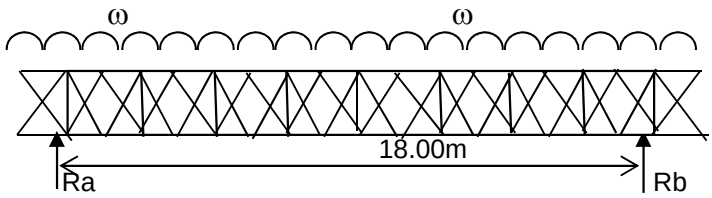
Notes:

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

18m X-Beam Results

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**



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*0.11
= 1.65 kN

so maximum moment is as above

Ultimate Mu= Wf*18^2/8
= (1.65*18^2)/8
= 66.83 kNm

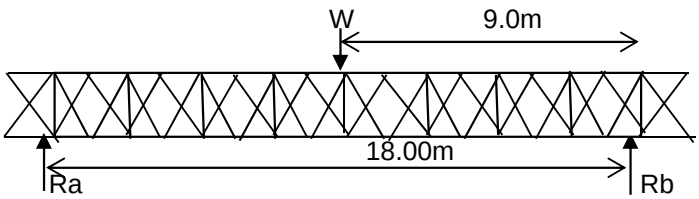
and for allowable value

allowable max moment= 66.83/1.50
= 44.55 kNm

Moment values	**Ultimate**	**66.83 kNm**
	Allowable	**44.55 kNm**

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**



Max Moment= ML/4

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

W= 1.50*10
= 15.00 kN

apply factor from above

Wf= 15*.94
= 14.10 kN

so maximum moment is as above

Ultimate Mu= Wf*L/4
= 14.10*18/4
= 63.45 kNm

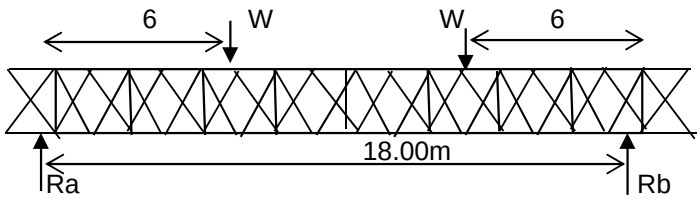
and for allowable value

allowable max moment= 63.45/1.50
= 42.30 kNm

Moment values	**Ultimate**	**63.45 kNm**
	Allowable	**42.30 kNm**

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= 1.50*10
15.00 kN

apply factor from above

Wf= 15.00*0.69
= 10.35 kN

so maximum moment is as above

Ultimate Mu= Wf*L/3
= (10.35*18)/3
= 62.10 kNm

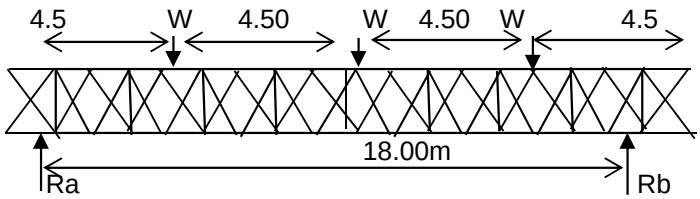
and for allowable value

allowable max moment= 62.10/1.50
= 41.40 kNm

Moment values	**Ultimate**	**62.10 kNm**
	Allowable	**41.40 kNm**

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.

Max Moment= ML/2

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15.00*0.48
= 7.20 kN

so maximum moment is as above

Ultimate Mu= Wf*L/2
= (7.20*18)/2
= 64.80 kNm

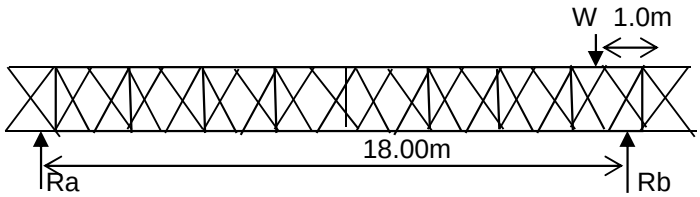
and for allowable value

allowable max moment= 64.80/1.50
= 43.20 kNm

Moment values	**Ultimate**	**64.80 kNm**
	Allowable	**43.20 kNm**

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.

Max Shear Rb= W*8/9

so for ultimate condition

W= 1.50*10.0
15.00 kN

apply factor from above

Wf= 15.00*3.72
= 55.80 kN

so maximum shear is as above

Ultimate Qu= Wf*17/18
= (55.80*17)/18
= 52.70 kN

and for allowable value

allowable max shear= 52.70/1.50
= 35.13 kN

Shear values	**Ultimate**	**52.70 kN**
	Allowable	**35.13 kN**

X-BEAM

Loadcase No.		Ultimate Moment	Allowable 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 No.		Ultimate Shear	Allowable 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	*35.0*	*23.3*	*17.5*	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	*70.0*	*70.0*	*70.0*	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	*70.0*	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	*35.0*	*35.0*	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	*23.3*	*23.3*	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

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

Graph Summary of Allowable Working Loads for an X-Beam to BS EN 1999-1-1

ALAN WHITE DESIGN