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

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Brief

The brief is to prepare calculated values for the capacity of the Apollo Ladder Beam to BS EN 1999-1-1.

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

Alloy

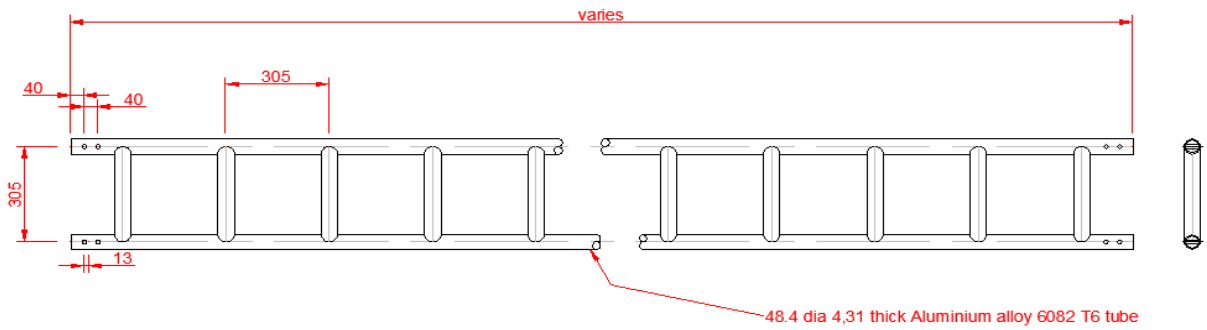
The alloy used is 6082 T6:

f_o= 255 N/mm^2

f_u= 295 N/mm^2

Layout

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



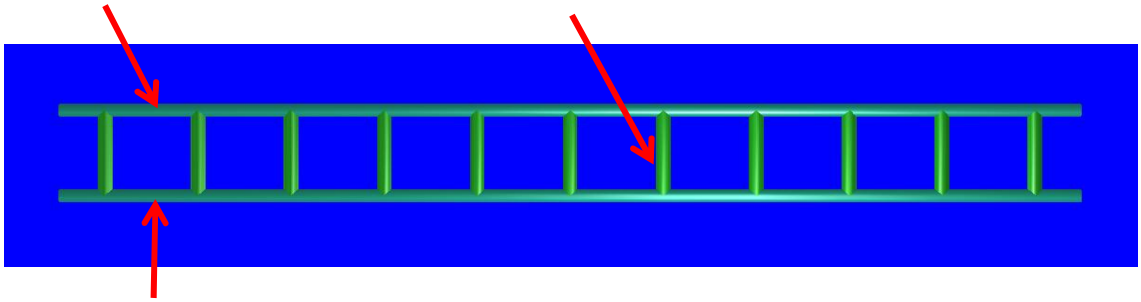
Design

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 Ladder Beam shown below, larger spans are scaled versions of below)

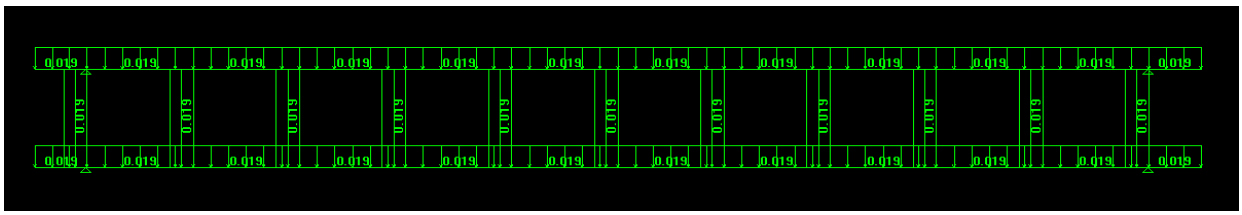
Top Boom Alu Scaffold Tube Vertical Alu Scaff Tube



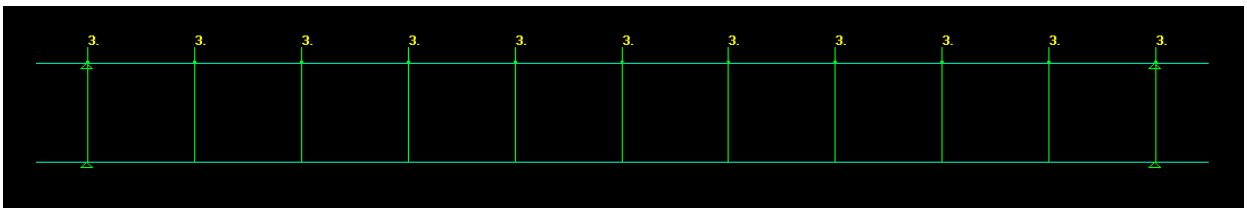
Bottom Boom Alu Scaffold Tube

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

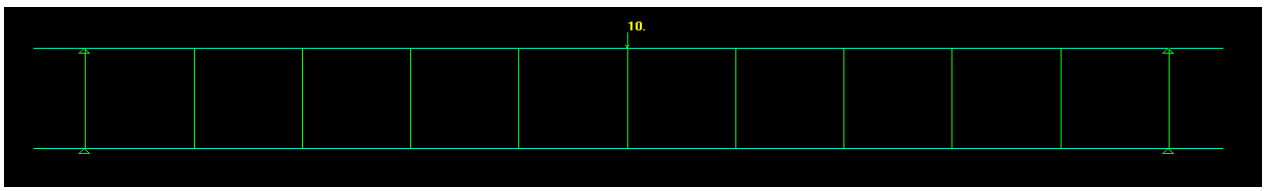
Load Case 1 Self Weight
Self weight of all booms and verticals factored by 1.15 to account for all connections



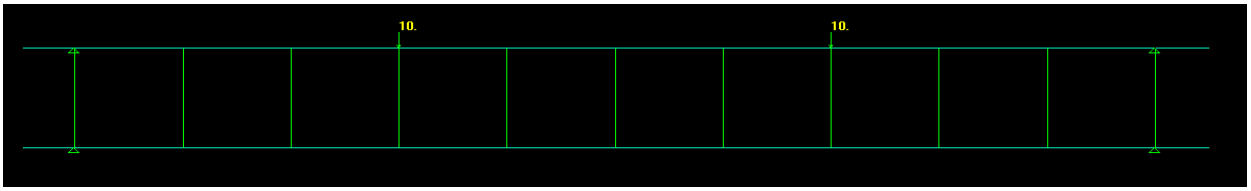
Load Case 2 UDL
10kN/m Load Applied to top boom over full length of the Ladder Beam at node points



Load Case 3 Central Point Load
10kN Point Load Applied to Centre of Top Boom of the Ladder Beam

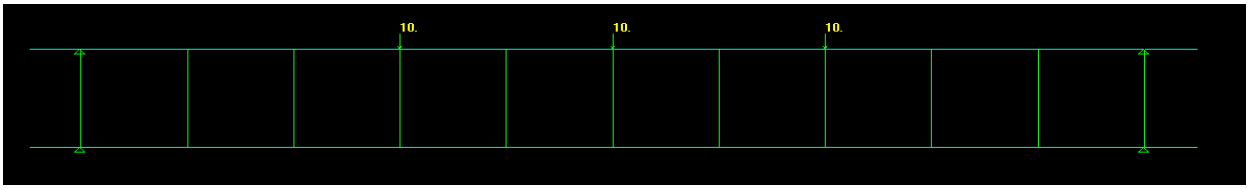


Load Case 4 Two Point Loads
2No 10kN point loads applied at third points along the top boom of the Ladder Beam.



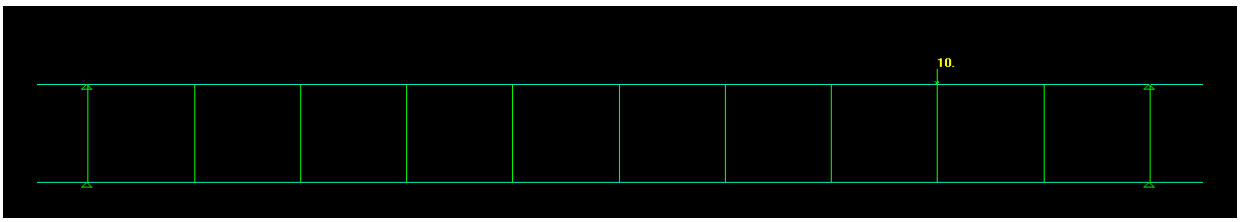
Load Case 5 Three Point Loads

3No 10kN Point Loads applied at quarter points along the Ladder Beam



Load Case 6 End Shear

10kN Point Load applied 0.6m 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

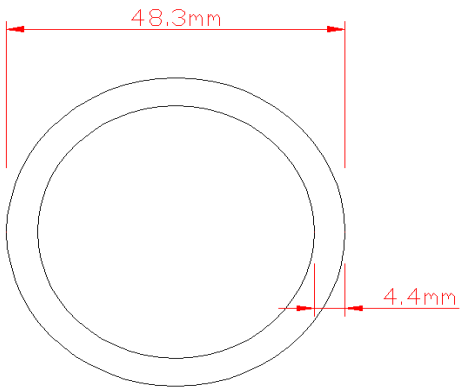
Above Combinations were checked for the following design factors:

γ_D= 1.25

γ_L= 1.50

Boom 48.3 x 4.4mm CHS

Boom 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= 255N/mm^2
	=	0.99		(PD6702 Table3)
Class A, without welds, Internal parts	β_1=	11ε		
	=	11*0.99		
	=	10.89		
	<	10.98		Not Class 1
	β_2=	13ε		
	=	13*0.99		
	=	12.87		
	>	10.98		Class 2

Section is class 2

Boom 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)

$= 1.35$

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

$f_o = 255\ N/mm^2$

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

$= 1.35*6.11*255/1100$

$M_{c,Rd} = 1.91\ kNm$

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

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

$= 6.11*0.64$

$= 3.91\ cm^3$

$f_u = 295\ N/mm^2$

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

$= 3.91*295/1250$

$M_{u,Rd} = 0.92\ kNm$

$M_{Rd,x} = 0.92\ kNm$ lesser value of $M_{c,Rd}$ / $M_{u,Rd}$

Boom CHS Shear Capacity (6.2.6)

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

$A_v = 0.6A$

$A_v = 0.6*607$

$A_v = 364.20\ mm^2$

$\gamma_{M1} = 1.1$

$f_o = 255\ N/mm^2$

$= 364.20*255/(SQRT(3)*1100)$

$V_{Rd} = 48.74\ kN$

Boom CHS Axial Comp Capacity @ 257mm (effective length of beam)

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

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

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

$k = 0.50$

$L = 257\ mm$

N_{cr} = ((PI()^2)*70000*147654)/((0.5^2)*(257^2))
= 6,177,841.29 N

$\lambda = \sqrt{A_{eff}}\, f_o / N_{cr}$ (6.3.1.2)
= 0.16 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
λ_o= 0.10 Table 6.6
Φ = 0.52
X = 0.97

$N_{b,Rd}$ = 0.65*0.97*607*255/1100
= 88.72 kN

Boom CHS Axial Tension Capacity (6.2.3)

1. General yielding

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

f_o = 255N/mm^2
A_g = 607mm^2
γ_{M1} = 1.1

= 607*255/1100
= 140.71 kN

2. Local failure

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

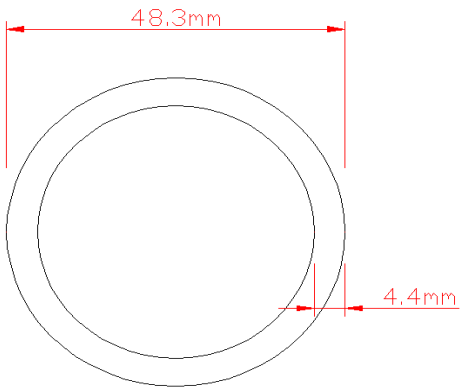
f_u = 295N/mm^2
A_{net} = A* $\rho_{u,haz}$
= 607*0.64
= 388.5mm^2
γ_{M1} = 1.25

= 388.5*295/1250
= 91.69 kN

Lesser Value= 91.69 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= 255N/mm^2
=	0.99	(PD6702 Table3)

Class A, without welds, Internal parts

β_1=	11ε	
=	11*0.99	
=	10.89	
<	10.98	
β_2=	13ε	
=	13*0.99	
=	12.87	
>	10.98	Class 2

Section is class 2

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)

$= 1.35$

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

$f_o = 255\ N/mm^2$

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

$= 1.35*6.11*255/1100$

$M_{c,Rd} = 1.91\ kNm$

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

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

$= 6.11*0.64$

$= 3.91\ cm^3$

$f_u = 295\ N/mm^2$

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

$= 3.91*295/1250$

$M_{u,Rd} = 0.92\ kNm$

$M_{Rd,x} = 0.92\ kNm$ lesser value of $M_{c,Rd}$ / $M_{u,Rd}$

Vertical CHS Shear Capacity (6.2.6)

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

$A_v = 0.6A$

$A_v = 0.6*607$

$A_v = 364.20\ mm^2$

$\gamma_{M1} = 1.1$

$f_o = 255\ N/mm^2$

$= 364.20*255/(SQRT(3)*1100)$

$V_{Rd} = 48.74\ kN$

Vertical CHS Axial Comp Capacity @ 257mm (effective length of beam)

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

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

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

$k = 0.50$

$L = 257\ mm$

N_{cr} = ((PI()^2)*70000*147654)/((0.5^2)*(257^2))
= 6,177,841.29 N

$\lambda = \sqrt{A_{eff}}\, f_o / N_{cr}$ (6.3.1.2)
= 0.16 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
λ_o= 0.10 Table 6.6
Φ = 0.52
X = 0.97

$N_{b,Rd}$ = 0.65*0.97*607*255/1100
= 88.72 kN

Vertical CHS Axial Tension Capacity (6.2.3)

1. General yielding

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

f_o = 255N/mm^2
A_g = 607mm^2
γ_{M1} = 1.1

= 607*255/1100
= 140.71 kN

2. Local failure

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

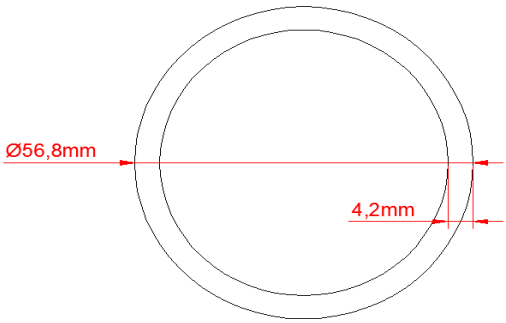
f_u = 295N/mm^2
A_{net} = A* $\rho_{u,haz}$
= 607*0.64
= 388.5mm^2
γ_{M1} = 1.25

= 388.5*295/1250
= 91.69 kN

Lesser Value= 91.69 kN

6mm Fillet Weld around 48.3 x 4.4mm CHS

Weld CHS Layout



Section Properties

A=	694	mm^2
I=	241560	mm^4
W_{el}=	8506	mm^3
W_{pl}=	11483	mm^3
ry=	18.6	mm

Weld Moment Capacity

$M_{c,Rd} = W_{el} f_w / \gamma_{M2}$

$W_{el} =$ 8.51 cm^3

$f_w =$ 190 N/mm^2

$\gamma_{M2} =$ 1.25 (8.1.1)

$= 8.51*190/1250$

$M_{c,Rd} =$ 1.29 kNm

Weld Shear Capacity

$V_{Rd} = A_w f_o / \gamma_{M1}$

$A_w =$ 0.6A

$A_w =$ 0.6*694

$A_w =$ 416.40 mm^2

$\gamma_{M2} =$ 1.25

$f_w =$ 190 N/mm^2

$= 416.4*190/1250$

$V_{Rd} =$ 63.29 kN

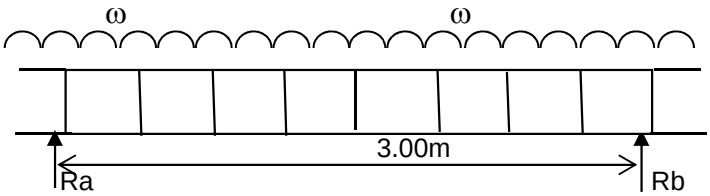
Note: Weld Moment Capacity and Shear Strength greater than tube capacity, therefore weld is not critical.

3m Ladder Beam Results

3m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	1.45	0.64
	Shear	V_{Rd}	48.74	10.36	4.71
	Tension	$N_{o,Rd}$	91.69	25.89	3.54
	Compression	$N_{b,Rd}$	88.72	25.89	3.43
	Deflection	d	30	12.98	2.31
	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	$M_{c,Rd}$	0.92	2.03	0.45
	Shear	V_{Rd}	48.74	16.63	2.93
	Tension	$N_{o,Rd}$	91.69	0.00	91686.00
	Compression	$N_{b,Rd}$	88.72	2.27	39.14
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6}$ < 1.0		1.00	0.45
				Factor	**0.45**



Max Moment= $ML^2/8$

so for ultimate condition

W= 1.5*10
15.00 kN

apply factor from above

Wf= 15*0.45
= 6.75 kN

so maximum moment is as above

Ultimate Mu= $Wf*L^2/8$
= (6.75*3^2)/8
= 7.59 kNm

and for allowable value

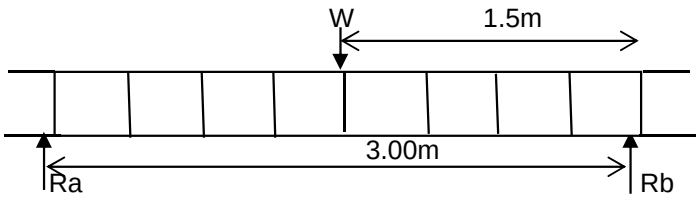
allowable Ma= 7.59/1.50
= 5.06 kNm

Moment values	**Ultimate**	**7.59 kNm**
	Allowable	**5.06 kNm**

3m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	0.68	1.36
	Shear	V_{Rd}	48.74	3.83	12.73
	Tension	$N_{o,Rd}$	91.69	14.30	6.41
	Compression	$N_{b,Rd}$	88.72	13.88	6.39
	Deflection	d	30.00	8.21	3.65
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	1.21
Vertical	Max Moment	$M_{c,Rd}$	0.92	0.90	1.02
	Shear	V_{Rd}	48.74	7.41	6.58
	Tension	$N_{o,Rd}$	91.69	0.02	4584.30
	Compression	$N_{b,Rd}$	88.72	0.01	11089.99
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	1.02
	Max Comp	$N_{b,Rd}$	88.72	7.36	12.05
	Moment	$M_{c,Rd}$	0.92	0.00	922.76
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	12.01
				Factor	**1.02**



Max Moment= ML/4

so for ultimate condition

W= 1.50*10
= 15.00 kN

apply factor from above

Wf= 15*1.02
= 15.30 kN

so maximum moment is as above

Ultimate Mu= Wf*L/4
= 15.3*3/4
= 11.48 kNm

and for allowable value

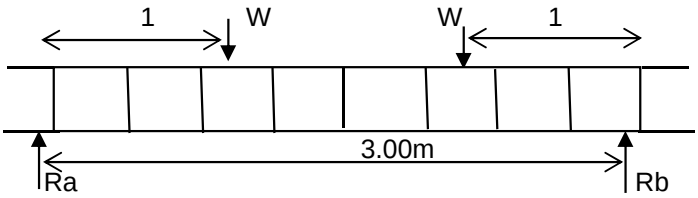
allowable Ma= 11.48/1.50
= 7.65 kNm

Moment values	**Ultimate**	**11.48 kNm**
	Allowable	**7.65 kNm**

3m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Max Moment	$M_{c,Rd}$	0.92	1.12	0.82
	Shear	V_{Rd}	48.74	7.60	6.42
	Tension	$N_{o,Rd}$	91.69	22.57	4.06
	Compression	$N_{b,Rd}$	88.72	5.09	17.42
	Deflection	d	30.00	10.52	2.85
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.81
	Max Comp	$N_{b,Rd}$	88.72	22.56	3.93
	Moment	$M_{c,Rd}$	0.92	1.11	0.83
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.72
Vertical	Max Moment	$M_{c,Rd}$	0.92	1.70	0.54
	Shear	V_{Rd}	48.74	13.92	3.50
	Tension	$N_{o,Rd}$	91.69	0.02	4167.55
	Compression	$N_{b,Rd}$	88.72	0.03	2957.33
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.54
	Max Comp	$N_{b,Rd}$	88.72	7.364	12.05
	Moment	$M_{c,Rd}$	0.92	0.908	1.02
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.96
				Factor	**0.54**



Max Moment= ML/3

so for ultimate condition

W= 1.50*10

15.00 kN

apply factor from above

Wf= 15*0.54

= 8.10 kN

so maximum moment is as above

Ultimate Mu= Wf*3/3

= (8.10*3)/3

= 8.10 kNm

and for allowable value

allowable Ma= 8.10/1.50

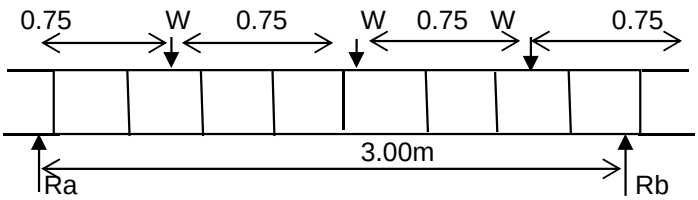
= 5.40 kNm

Moment values	**Ultimate**	**8.10 kNm**
	Allowable	**5.40 kNm**

3m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	1.66	0.55
	Shear	V_{Rd}	48.74	11.35	4.29
	Tension	$N_{o,Rd}$	91.69	36.75	2.49
	Compression	$N_{b,Rd}$	88.72	36.75	2.41
	Deflection	d	30.00	18.66	1.61
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.49
Vertical	Max Moment	$M_{c,Rd}$	0.92	2.57	0.36
	Shear	V_{Rd}	48.74	21.09	2.31
	Tension	$N_{o,Rd}$	91.69	0.00	91686.00
	Compression	$N_{b,Rd}$	88.72	0.10	887.20
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.36
	Max Comp	$N_{b,Rd}$	88.72	7.34	12.09
	Moment	$M_{c,Rd}$	0.92	1.79	0.51
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.50
				Factor	**0.36**



Max Moment= ML/2

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15*0.36
= 5.40 kN

so maximum moment is as above

Ultimate Mu= Wf*L/2
= (5.4*3/2)
= 8.10 kNm

and for allowable value

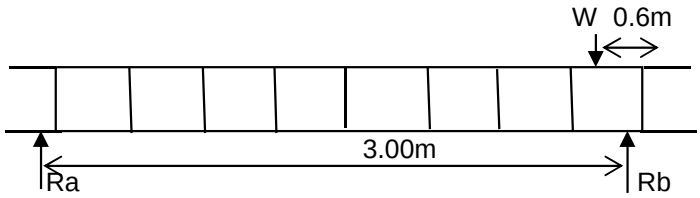
allowable Ma= 8.1/1.5
= 5.40 kNm

Moment values	**Ultimate**	**8.10 kNm**
	Allowable	**5.40 kNm**

3m Ladder Beam Results

Load Comb. 5 End Shear 10kN load applied at a 0.6m distance from the support

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Max Moment	$M_{c,Rd}$	0.92	0.95	0.97
	Shear	V_{Rd}	48.74	6.34	7.69
	Tension	$N_{o,Rd}$	91.69	8.24	11.13
	Compression	$N_{b,Rd}$	88.72	3.37	26.33
	Deflection	d	30.00	4.64	6.47
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.96
	Max Comp	$N_{b,Rd}$	88.72	8.24	10.77
	Moment	$M_{c,Rd}$	0.92	0.34	2.71
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	2.28
Vertical	Max Moment	$M_{c,Rd}$	0.92	1.30	0.71
	Shear	V_{Rd}	48.74	20.91	2.33
	Tension	$N_{o,Rd}$	91.69	0.02	4584.30
	Compression	$N_{b,Rd}$	88.72	0.09	953.98
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.71
	Max Comp	$N_{b,Rd}$	88.72	7.37	12.04
	Moment	$M_{c,Rd}$	0.92	0.59	1.55
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	1.42
				Factor	**0.71**



Max Shear Rb= W*2.4/3

so for ultimate condition

W= 1.50*10

15.00 kN

apply factor from above

Wf= 15*0.71

= 10.65 kN

so maximum shear is as above

Ultimate Qu= Wf*2.4/3

= (10.65*2.4)/3

= 8.52 kN

and for allowable value

allowable Q_A= 8.52/1.50

= 5.68 kN

Shear values	**Ultimate**	**8.52 kN**
	Allowable	**5.68 kN**

3m Ladder Beam Results

Ladder Beam			
Loadcase No.		**Ultimate Moment**	**Allowable Moment**
1	UDL	7.59	5.06
2	Point	11.48	7.65
3	Third	8.10	5.40
4	Quarter	8.10	5.40

Loadcase No.		**Ultimate Shear**	**Allowable Shear**
5	End Shear	8.52	5.68

Max Allowable Moment = 5.0 kNm

Max Allowable Shear = 5.6 kN

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

ALAN WHITE DESIGN

For simply supported Apollo single Ladder Beam TO EUROCODE EN 1999-1

Allowable Bending Moment	5.0 kNm
Allowable Shear	5.6 kN

Type of Load		Clear span (m)										
		2	3	4	5	6	7	8	9	10	11	12
Uniformly Distributed load	kN/m	*5.6*	*3.7*	2.5	1.6	1.1	0.8	0.6	0.5	0.4	0.3	0.3
Total UDL	kN	*11.2*	*11.2*	10.0	8.0	6.7	5.7	5.0	4.4	4.0	3.6	*3.3*
Single point load (mid Point)	kN	10.0	6.7	5.0	4.0	3.3	2.9	2.5	2.2	2.0	1.8	1.7
Two point loads (third points)	Each kN	*5.6*	5.0	3.8	3.0	2.5	2.1	1.9	1.7	1.5	1.4	1.3
Three point loads (quarter points)	Each kN	*3.7*	3.3	2.5	2.0	1.7	1.4	1.3	1.1	1.0	0.9	0.8

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 11kN 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. Restraint point must support both top and bottom booms at restraint location.

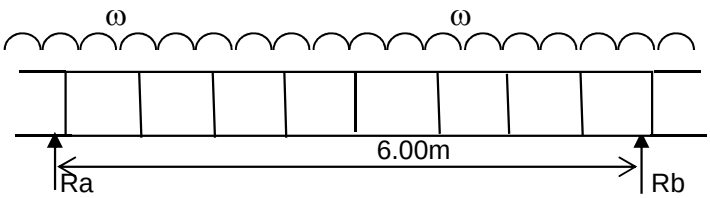
6m Ladder Beam Results

6m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	3.24	0.29
	Shear	V_{Rd}	48.74	21.85	2.23
	Tension	$N_{o,Rd}$	91.69	126.77	0.72
	Compression	$N_{b,Rd}$	88.72	126.77	0.70
	Deflection	d	60	66.33	0.90
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.22
Vertical	Moment	$M_{c,Rd}$	0.92	4.65	0.20
	Shear	V_{Rd}	48.74	38.14	1.28
	Tension	$N_{o,Rd}$	91.69	0.00	91686.00
	Compression	$N_{b,Rd}$	88.72	2.30	38.62
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.20

Factor **0.20**



Max Moment= $ML^2/8$

so for ultimate condition

W= 1.5*10
15.00 kN

apply factor from above

Wf= 15*0.20
= 3.00 kN

so maximum moment is as above

Ultimate Mu= $Wf*L^2/8$
= (3.00*6^2)/8
= 13.50 kNm

and for allowable value

allowable Ma= 13.50/1.50
= 9.00 kNm

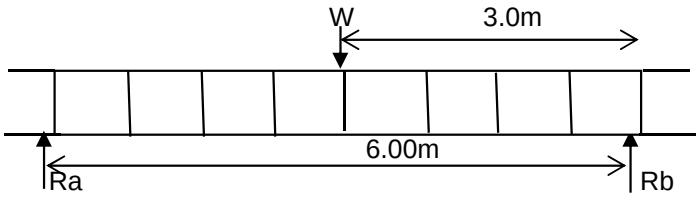
Moment values	**Ultimate**	**13.50 kNm**
	Allowable	**9.00 kNm**

6m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	0.71	1.30
	Shear	V_{Rd}	48.74	3.82	12.75
	Tension	$N_{o,Rd}$	91.69	32.62	2.81
	Compression	$N_{b,Rd}$	88.72	32.62	2.72
	Deflection	d	60.00	21.60	2.78
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.97
Vertical	Moment	$M_{c,Rd}$	0.92	1.15	0.80
	Shear	V_{Rd}	48.74	7.56	6.45
	Tension	$N_{o,Rd}$	91.69	7.36	12.46
	Compression	$N_{b,Rd}$	88.72	0.00	22179.99
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.80

Factor **0.80**



Max Moment= ML/4

so for ultimate condition

W= 1.50*10
= 15.00 kN

apply factor from above

Wf= 15*0.80
= 12.00 kN

so maximum moment is as above

Ultimate Mu= Wf*L/4
= 12.00*6/4
= 18.00 kNm

and for allowable value

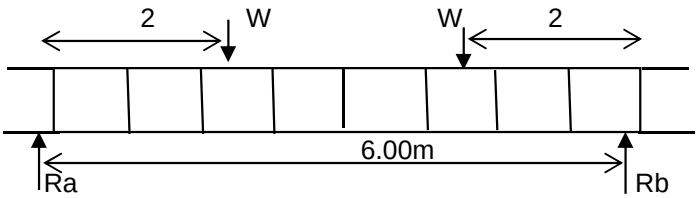
allowable Ma= 18.00/1.50
= 12.00 kNm

Moment values	**Ultimate**	**18.00 kNm**
	Allowable	**12.00 kNm**

6m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	1.16	0.79
	Shear	V_{Rd}	48.74	7.62	6.40
	Tension	$N_{o,Rd}$	91.69	54.40	1.69
	Compression	$N_{b,Rd}$	88.72	54.40	1.63
	Deflection	d	60.00	27.01	2.22
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.59
Vertical	Max Moment	$M_{c,Rd}$	0.92	1.83	0.51
	Shear	V_{Rd}	48.74	14.96	3.26
	Tension	$N_{o,Rd}$	91.69	0.02	4584.30
	Compression	$N_{b,Rd}$	88.72	0.01	11089.99
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.51
	Max Comp	$N_{b,Rd}$	88.72	7.364	12.05
	Moment	$M_{c,Rd}$	0.92	0.916	1.01
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.95
				Factor	**0.51**



Max Moment= ML/3

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15*0.51
= 7.65 kN

so maximum moment is as above

Ultimate Mu= Wf*L/3
= (7.65*6)/3
= 15.30 kNm

and for allowable value

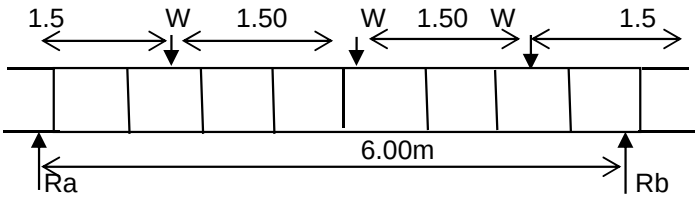
allowable Ma= 15.30/1.50
= 10.20 kNm

Moment values	**Ultimate**	**15.30 kNm**
	Allowable	**10.20 kNm**

6m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	1.74	0.53
	Shear	V_{Rd}	48.74	11.38	4.28
	Tension	$N_{o,Rd}$	91.69	80.55	1.14
	Compression	$N_{b,Rd}$	88.72	80.55	1.10
	Deflection	d	60.00	43.29	1.39
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.39
Vertical	Moment	$M_{c,Rd}$	0.92	2.71	0.34
	Shear	V_{Rd}	48.74	22.25	2.19
	Tension	$N_{o,Rd}$	91.69	0.02	4584.30
	Compression	$N_{b,Rd}$	88.72	0.02	3857.39
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.34
				Factor	**0.34**



Max Moment= ML/2

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15*0.34
= 5.10 kN

so maximum moment is as above

Ultimate Mu= Wf*L/2
= (5.10*6/2)
= 15.30 kNm

and for allowable value

allowable Ma= 15.30/1.5
= 10.20 kNm

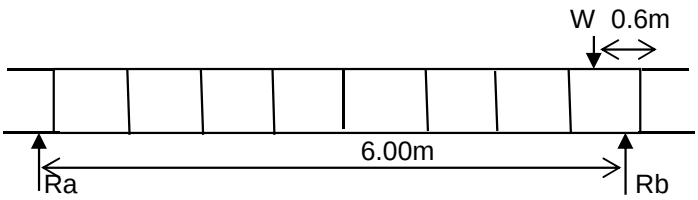
Moment values	**Ultimate**	**15.30 kNm**
	Allowable	**10.20 kNm**

6m Ladder Beam Results

Load Comb. 5 End Shear 10kN load applied at a 0.6m distance from the support

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	1.05	0.88
	Shear	V_{Rd}	48.74	7.23	6.74
	Tension	$N_{o,Rd}$	91.69	11.26	8.14
	Compression	$N_{b,Rd}$	88.72	0.08	1137.44
	Deflection	d	60.00	5.97	10.05
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		0.73	0.65
Vertical	Max Moment	$M_{c,Rd}$	0.92	1.78	0.52
	Shear	V_{Rd}	48.74	11.69	4.17
	Tension	$N_{o,Rd}$	91.69	12.38	7.41
	Compression	$N_{b,Rd}$	88.72	0.08	1137.44
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.52
	Max Comp	$N_{b,Rd}$	88.72	12.38	7.17
	Moment	$M_{c,Rd}$	0.92	1.02	0.91
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.83

Factor **0.52**



Max Shear Rb= W*2/3

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15*0.52
= 7.80 kN

so maximum shear is as above

Ultimate Qu= Wf*5.4/6
= (7.80*5.4)/6
= 7.02 kN

and for allowable value

allowable Q_A= 7.80/1.50
= 5.20 kN

Shear values	**Ultimate**	**7.02 kN**
	Allowable	**5.20 kN**

6m Ladder Beam Results

Ladder Beam			
Loadcase No.		**Ultimate Moment**	**Allowable Moment**
1	UDL	13.50	9.00
2	Point	18.00	12.00
3	Third	15.30	10.20
4	Quarter	15.30	10.20

Loadcase No.		Ultimate Shear	Allowable Shear
5	End Shear	7.02	5.20

Max Allowable Moment = 9.0 kNm

Max Allowable Shear = 5.2 kN

From 6m Ladder Beam Analysis with restraints to compression chord at 1.0m c/c

ALAN WHITE DESIGN

For simply supported Apollo single Ladder Beam TO EUROCODE EN 1999-1

Allowable Bending Moment	9.0 kNm
Allowable Shear	5.2 kN

Allowable loads for load distributions

Type of Load		Clear span (m)										
		2	3	4	5	6	7	8	9	10	11	12
Uniformly Distributed load	kN/m	*5.2*	*3.5*	*2.6*	*2.1*	*1.7*	1.5	1.1	0.9	0.7	0.6	*0.5*
Total UDL	kN	*10.4*	*10.4*	*10.4*	*10.4*	*10.4*	10.3	9.0	8.0	7.2	6.5	*6.0*
Single point load (mid Point)	kN	*10.4*	*10.4*	9.0	7.2	6.0	5.1	4.5	4.0	3.6	3.3	3.0
Two point loads (third points)	Each kN	*5.2*	*5.2*	*5.2*	*5.2*	4.5	3.9	3.4	3.0	2.7	2.5	2.3
Three point loads (quarter points)	Each kN	*3.5*	*3.5*	*3.5*	*3.5*	3.0	2.6	2.3	2.0	1.8	1.6	1.5

Notes:

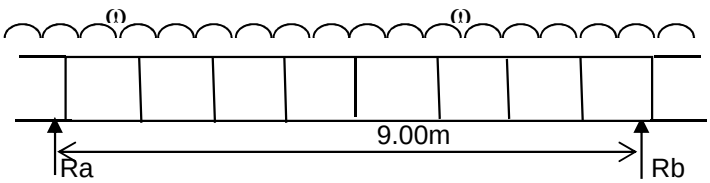
1. Above allowable loads may be increased by 1.11 for **wind loading only**
2. This table is provided as a guide only and assume all loads are applied at nodes. All scaffolds and structures should be checked by a qualified structural engineer. Loads indicated in italics and shaded are limited by shear.
3. Maximum capacity of a point load mid way between nodes is 11kN 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. Restraint point must support both top and bottom booms at restraint location.

9m Ladder Beam Results

9m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	5.12	0.18
	Shear	V_{Rd}	48.74	33.34	1.46
	Tension	$N_{o,Rd}$	91.69	303.59	0.30
	Compression	$N_{b,Rd}$	88.72	303.59	0.29
	Deflection	d	90	195.67	0.46
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.12
Vertical	Moment	$M_{c,Rd}$	0.92	7.29	0.13
	Shear	V_{Rd}	48.74	59.75	0.82
	Tension	$N_{o,Rd}$	91.69	0.00	91686.00
	Compression	$N_{b,Rd}$	88.72	2.30	38.62
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.13
				Factor	**0.12**



Max Moment= $ML^2/8$

so for ultimate condition

W= 1.5*10
15.00 kN

apply factor from above

Wf= 15*0.12
= 1.80 kN

so maximum moment is as above

Ultimate Mu= $Wf*L^2/8$
= (1.80*9^2)/8
= 18.23 kNm

and for allowable value

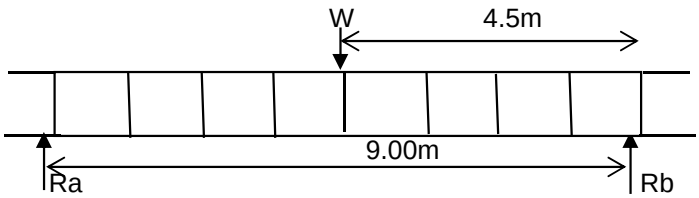
allowable Ma= 18.23/1.50
= 12.15 kNm

Moment values	**Ultimate**	**18.23 kNm**
	Allowable	**12.15 kNm**

9m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Max Moment	$M_{c,Rd}$	0.92	0.74	1.25
	Shear	V_{Rd}	48.74	3.91	12.47
	Tension	$N_{o,Rd}$	91.69	52.88	1.73
	Compression	$N_{b,Rd}$	88.72	51.60	1.72
	Deflection	d	90.00	70.41	1.28
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.80
	Max Comp	$N_{b,Rd}$	88.72	52.88	1.68
	Moment	$M_{c,Rd}$	0.92	0.63	1.46
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.85
Vertical	Max Moment	$M_{c,Rd}$	0.92	0.94	0.99
	Shear	V_{Rd}	48.74	7.67	6.36
	Tension	$N_{o,Rd}$	91.69	0.02	4584.30
	Compression	$N_{b,Rd}$	88.72	0.00	22179.99
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.99
	Max Comp	$N_{b,Rd}$	91.69	7.36	12.45
	Moment	$M_{c,Rd}$	0.92	0.00	922.76
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	12.41
				Factor	**0.80**



Max Moment= ML/4

so for ultimate condition

W= 1.50*10

= 15.00 kN

apply factor from above

Wf= 15*0.80

= 12.00 kN

so maximum moment is as above

Ultimate Mu= Wf*L/4

= 12.00*9/4

= 27.00 kNm

and for allowable value

allowable Ma= 27.00/1.50

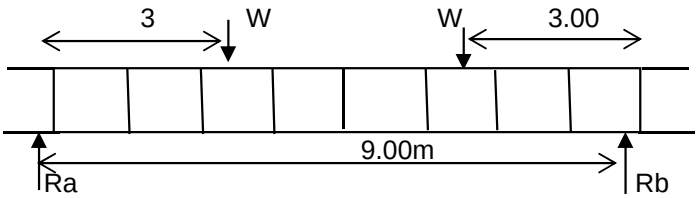
= 18.00 kNm

Moment values	**Ultimate**	**27.00 kNm**
	Allowable	**18.00 kNm**

9m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	1.26	0.73
	Shear	V_{Rd}	48.74	7.97	6.12
	Tension	$N_{o,Rd}$	91.69	90.52	1.01
	Compression	$N_{b,Rd}$	88.72	90.52	0.98
	Deflection	d	90.00	103.71	0.87
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.46
Vertical	Max Moment	$M_{c,Rd}$	0.92	1.91	0.48
	Shear	V_{Rd}	48.74	15.69	3.11
	Tension	$N_{o,Rd}$	91.69	0.02	4584.30
	Compression	$N_{b,Rd}$	88.72	0.00	22179.99
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.48
	Max Comp	$N_{b,Rd}$	88.72	7.36	12.05
	Moment	$M_{c,Rd}$	0.92	0.85	1.09
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	1.02
				Factor	**0.46**



Max Moment= ML/3

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15*0.46
= 6.90 kN

so maximum moment is as above

Ultimate Mu= Wf*L/3
= (6.90*9)/3
= 20.70 kNm

and for allowable value

allowable Ma= 20.70/1.50
= 13.80 kNm

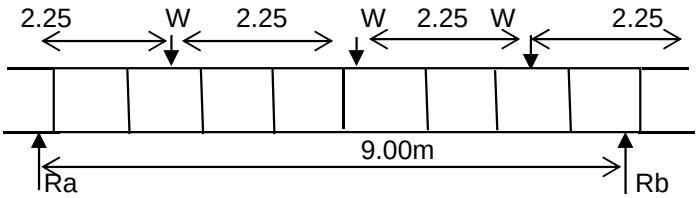
Moment values	**Ultimate**	**20.70 kNm**
	Allowable	**13.80 kNm**

9m Ladder Beam Results

Load Comb. 4 PL at quarter points

10kN load applied at each of the three quarter points

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	0.98	0.94
	Shear	V_{Rd}	48.74	11.42	4.27
	Tension	$N_{o,Rd}$	91.69	124.08	0.74
	Compression	$N_{b,Rd}$	88.72	124.08	0.72
	Deflection	d	90.00	147.19	0.61
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.44
Vertical	Max Moment	$M_{c,Rd}$	0.92	2.75	0.34
	Shear	V_{Rd}	48.74	22.50	2.17
	Tension	$N_{o,Rd}$	91.69	0.03	3056.20
	Compression	$N_{b,Rd}$	88.72	0.00	29573.32
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.34
	Max Comp	$N_{b,Rd}$	88.72	7.364	12.05
	Moment	$M_{c,Rd}$	0.92	1.832	0.50
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.49
				Factor	**0.34**



Max Moment= ML/2

so for ultimate condition

W= 1.50*10

15.00 kN

apply factor from above

Wf= 15*0.34

= 5.10 kN

so maximum moment is as above

Ultimate Mu= Wf*L/2

= (5.10*9/2)

= 22.95 kNm

and for allowable value

allowable Ma= 22.95/1.5

= 15.30 kNm

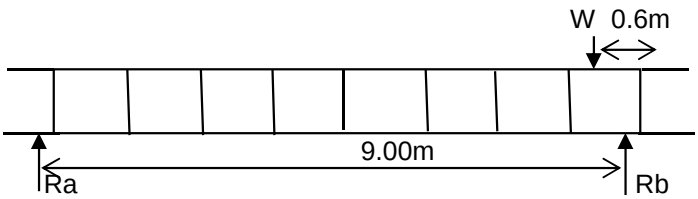
Moment values	**Ultimate**	**22.95 kNm**
	Allowable	**15.30 kNm**

9m Ladder Beam Results

Load Comb. 5 End Shear 10kN load applied at a 0.6m distance from the support

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	1.31	0.70
	Shear	V_{Rd}	48.74	7.52	6.48
	Tension	$N_{o,Rd}$	91.69	16.20	5.66
	Compression	$N_{b,Rd}$	88.72	16.20	5.48
	Deflection	d	90.00	13.84	6.50
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.66
Vertical	Max Moment	$M_{c,Rd}$	0.92	1.56	0.59
	Shear	V_{Rd}	48.74	12.85	3.79
	Tension	$N_{o,Rd}$	91.69	0.02	4584.30
	Compression	$N_{b,Rd}$	88.72	0.09	1031.63
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.59
	Max Comp	$N_{b,Rd}$	88.72	7.365	12.05
	Moment	$M_{c,Rd}$	0.92	0.877	1.05
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.99

Factor **0.59**



Max Shear Rb= W*2/3

so for ultimate condition

W= 1.50*10

15.00 kN

apply factor from above

Wf= 15*0.59

= 8.85 kN

so maximum shear is as above

Ultimate Qu= Wf*8.4/9

= (8.85*8.4)/9

= 8.26 kN

and for allowable value

allowable Q_A= 8.26/1.50

= 5.51 kN

Shear values	**Ultimate**	**8.26 kN**
	Allowable	**5.51 kN**

9m Ladder Beam Results

Ladder Beam			
Loadcase No.		**Ultimate Moment**	**Allowable Moment**
1	UDL	18.23	12.15
2	Point	27.00	18.00
3	Third	20.70	13.80
4	Quarter	22.95	15.30

Loadcase No.		Ultimate Shear	Allowable Shear
5	End Shear	8.26	5.51

Max Allowable Moment = 12.1 kNm

Max Allowable Shear = 5.5 kN

From 9m Ladder Beam Analysis with restraints to compression chord at 1.0m c/c

ALAN WHITE DESIGN

For simply supported Apollo single Ladder Beam TO EUROCODE EN 1999-1

Allowable Bending Moment	12.1 kNm
Allowable Shear	5.5 kN

Allowable loads for load distributions

Type of Load		Clear span (m)										
		2	3	4	5	6	7	8	9	10	11	12
Uniformly Distributed load	kN/m	*5.5*	*3.7*	*2.8*	*2.2*	*1.8*	*1.6*	*1.4*	1.2	1.0	0.8	*0.7*
Total UDL	kN	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	*11.0*	10.8	9.7	8.8	*8.1*
Single point load (mid Point)	kN	*11.0*	*11.0*	*11.0*	9.7	8.1	6.9	6.1	5.4	4.8	4.4	4.0
Two point loads (third points)	Each kN	*5.5*	*5.5*	*5.5*	*5.5*	*5.5*	5.2	4.5	4.0	3.6	3.3	3.0
Three point loads (quarter points)	Each kN	*3.7*	*3.7*	*3.7*	*3.7*	*3.7*	3.5	3.0	2.7	2.4	2.2	2.0

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 11kN 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. Restraint point must support both top and bottom booms at restraint location.

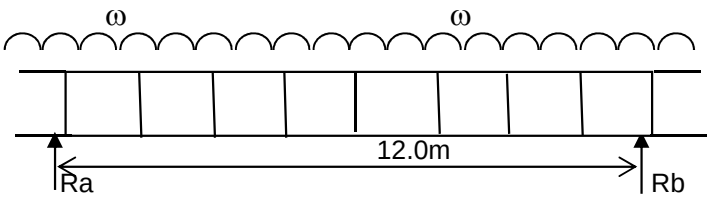
12m Ladder Beam Results

12m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	7.12	0.13
	Shear	V_{Rd}	48.74	44.83	1.09
	Tension	$N_{o,Rd}$	91.69	556.35	0.16
	Compression	$N_{b,Rd}$	88.72	556.35	0.16
	Deflection	d	120	460.58	0.26
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.08
Vertical	Moment	$M_{c,Rd}$	0.92	9.94	0.09
	Shear	V_{Rd}	48.74	81.46	0.60
	Tension	$N_{o,Rd}$	91.69	0.00	91686.00
	Compression	$N_{b,Rd}$	88.72	2.30	38.62
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.09

Factor **0.08**



Max Moment= $ML^2/8$

so for ultimate condition

W= 1.5*10
15.00 kN

apply factor from above

Wf= 15*0.08
= 1.20 kN

so maximum moment is as above

Ultimate Mu= $Wf*L^2/8$
= (1.20*12^2)/8
= 21.60 kNm

and for allowable value

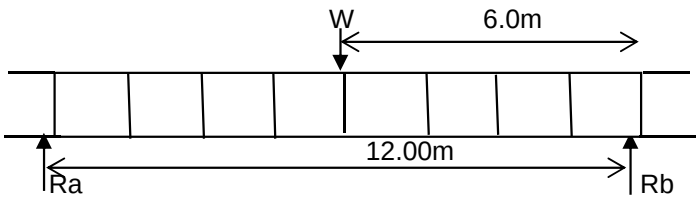
allowable Ma= 21.60/1.50
= 14.40 kNm

Moment values	**Ultimate**	**21.60 kNm**
	Allowable	**14.40 kNm**

12m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	0.77	1.20
	Shear	V_{Rd}	48.74	3.96	12.30
	Tension	$N_{o,Rd}$	91.69	72.66	1.26
	Compression	$N_{b,Rd}$	88.72	72.66	1.22
	Deflection	d	120.00	77.20	1.55
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.66
Vertical	Max Moment	$M_{c,Rd}$	0.92	0.95	0.97
	Shear	V_{Rd}	48.74	7.78	6.27
	Tension	$N_{o,Rd}$	91.69	0.02	4584.30
	Compression	$N_{b,Rd}$	88.72	0.00	22179.99
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.97
	Max Comp	$N_{b,Rd}$	88.72	7.364	12.05
	Moment	$M_{c,Rd}$	0.92	0.001	922.76
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	12.01
				Factor	**0.66**



Max Moment= ML/4

so for ultimate condition

W= 1.50*10

= 15.00 kN

apply factor from above

Wf= 15*0.66

= 9.90 kN

so maximum moment is as above

Ultimate Mu= Wf*L/4

= 9.90*12/4

= 29.70 kNm

and for allowable value

allowable Ma= 29.70/1.50

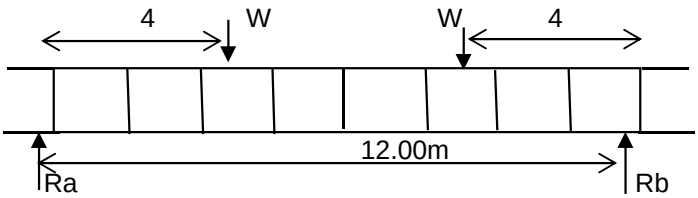
= 19.80 kNm

Moment values	**Ultimate**	**29.70 kNm**
	Allowable	**19.80 kNm**

12m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	1.27	0.72
	Shear	V_{Rd}	48.74	7.71	6.32
	Tension	$N_{o,Rd}$	91.69	124.50	0.74
	Compression	$N_{b,Rd}$	88.72	124.50	0.71
	Deflection	d	120.00	106.05	1.13
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.39
Vertical	Max Moment	$M_{c,Rd}$	0.92	1.85	0.50
	Shear	V_{Rd}	48.74	15.19	3.21
	Tension	$N_{o,Rd}$	91.69	0.02	4584.30
	Compression	$N_{b,Rd}$	88.72	0.00	22179.99
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.50
	Max Comp	$N_{b,Rd}$	88.72	7.364	12.05
	Moment	$M_{c,Rd}$	0.92	0.924	1.00
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.94
				Factor	**0.39**



Max Moment= ML/3

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15*0.39
= 5.85 kN

so maximum moment is as above

Ultimate Mu= Wf*L/3
= (5.85*12)/3
= 23.40 kNm

and for allowable value

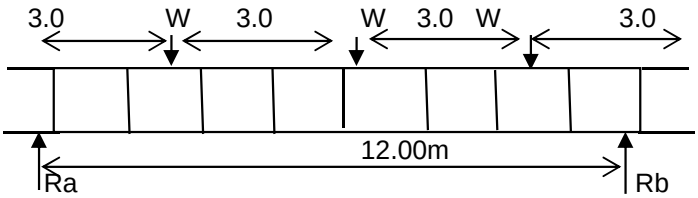
allowable Ma= 23.40/1.50
= 15.60 kNm

Moment values	**Ultimate**	**23.40 kNm**
	Allowable	**15.60 kNm**

12m Ladder Beam Results

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

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	1.88	0.49
	Shear	V_{Rd}	48.74	11.46	4.25
	Tension	$N_{o,Rd}$	91.69	175.60	0.52
	Compression	$N_{b,Rd}$	88.72	175.60	0.51
	Deflection	d	120.00	152.32	0.79
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.27
Vertical	Max Moment	$M_{c,Rd}$	0.92	2.76	0.33
	Shear	V_{Rd}	48.74	22.61	2.16
	Tension	$N_{o,Rd}$	91.69	0.03	3056.20
	Compression	$N_{b,Rd}$	88.72	0.00	22179.99
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.33
	Max Comp	$N_{b,Rd}$	88.72	7.364	12.05
	Moment	$M_{c,Rd}$	0.92	1.837	0.50
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.49
				Factor	**0.27**



Max Moment= ML/2

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15*0.27
= 4.05 kN

so maximum moment is as above

Ultimate Mu= Wf*L/2
= (4.05*12/2)
= 24.30 kNm

and for allowable value

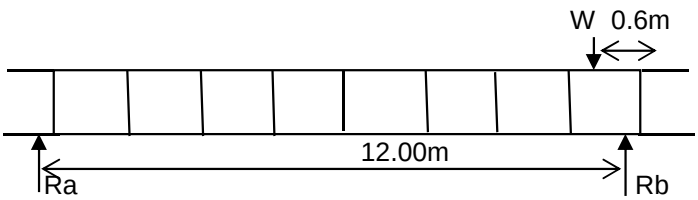
allowable Ma= 24.30/1.5
= 16.20 kNm

Moment values	**Ultimate**	**24.30 kNm**
	Allowable	**16.20 kNm**

12m Ladder Beam Results

Load Comb. 5 End Shear 10kN load applied at a 0.6m distance from the support

Element	Action	Formula	Capacity	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.92	1.09	0.85
	Shear	V_{Rd}	48.74	7.666	6.36
	Tension	$N_{o,Rd}$	91.69	19.179	4.78
	Compression	$N_{b,Rd}$	88.72	19.179	4.63
	Deflection	d	120.00	8.1	14.81
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.77
Vertical	Max Moment	$M_{c,Rd}$	0.92	1.60	0.58
	Shear	V_{Rd}	48.74	13.12	3.72
	Tension	$N_{o,Rd}$	91.69	0.02	4584.30
	Compression	$N_{b,Rd}$	88.72	0.09	953.98
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.58
	Max Comp	$N_{b,Rd}$	88.72	7.365	12.05
	Moment	$M_{c,Rd}$	0.92	0.912	1.01
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.95
				Factor	**0.58**



Max Shear Rb= W*2/3

so for ultimate condition

W= 1.50*10
15.00 kN

apply factor from above

Wf= 15*0.58
= 8.70 kN

so maximum shear is as above

Ultimate Qu= Wf*11.4/12
= (8.70*8.4)/9
= 8.12 kN

and for allowable value

allowable Q_A= 8.12/1.50
= 5.41 kN

Shear values	**Ultimate**	**8.12 kN**
	Allowable	**5.41 kN**

12m Ladder Beam Results

Ladder Beam			
Loadcase No.		**Ultimate Moment**	**Allowable Moment**
1	UDL	21.60	14.40
2	Point	29.70	19.80
3	Third	23.40	15.60
4	Quarter	24.30	16.20

Loadcase No.		**Ultimate Shear**	**Allowable Shear**
5	End Shear	8.12	5.41

Max Allowable Moment = 14.4 kNm

Max Allowable Shear = 5.4 kN

From 12m Ladder Beam Analysis with restraints to compression chord at 1.0m c/c

ALAN WHITE DESIGN

For simply supported Apollo single Ladder Beam TO EUROCODE EN 1999-1

Allowable Bending Moment	14.4 kNm
Allowable Shear	5.4 kN

Allowable loads for load distributions

		2	3	4	5	6	7	8	9	10	11	12
Uniformly Distributed load	kN/m	*5.4*	*3.6*	*2.7*	*2.2*	*1.8*	*1.5*	*1.4*	*1.2*	*1.1*	1.0	*0.8*
Total UDL	kN	*10.8*	*10.8*	*10.8*	*10.8*	*10.8*	*10.8*	*10.8*	*10.8*	*10.8*	10.5	*9.6*
Single point load (mid Point)	kN	*10.8*	*10.8*	*10.8*	*10.8*	9.6	8.2	7.2	6.4	5.8	5.2	4.8
Two point loads (third points)	Each kN	*5.4*	*5.4*	*5.4*	*5.4*	*5.4*	*5.4*	*5.4*	4.8	4.3	3.9	3.6
Three point loads (quarter points)	Each kN	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	3.2	2.9	2.6	2.4

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 11kN 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. Restraint point must support both top and bottom booms at restraint location.

Overall Ladder Beam Results

Overall Graded Results for Allowable Working Loads on an Ladder Beam

ALAN WHITE DESIGN

For simply supported Apollo Ladder Beam with a compression chord restraint at 1m intervals

Test Results

	Span(m)			
	3	6	9	12
Allowable Moment	5.0	9.0	12.1	14.4
Allowable Shear (Load on Vertical)	5.6	5.2	5.5	5.4

Allowable loads for load distributions from results

Type of Load	Clear span (m)				
		3	6	9	12
Uniformly Distributed load	kN/m	3.7	1.7	1.2	0.8
Total UDL	kN	11.2	10.4	10.8	9.6
Single point load (mid Point)	kN	6.7	6.0	5.4	4.8
Two point loads (third points)	Each kN	5.0	4.5	4.0	3.6
Three point loads (quarter points)	Each kN	3.3	3.0	2.7	2.4

Extrapolated Allowable loads for load distributions

Type of Load	Clear span (m)										
		2	3	4	5	6	7	8	9	10	11	12
Uniformly Distributed load	kN/m	5.6	3.7	2.6	2.1	1.7	1.5	1.4	1.2	1.0	1.0	0.8
Total UDL	kN	11.2	11.2	10.4	10.4	10.4	10.3	11.0	10.8	10.7	10.5	9.6
Single point load (mid Point)	kN	10.0	9.5	9.0	7.2	6.0	5.1	6.1	5.4	4.8	5.2	4.8
Two point loads (third points)	Each kN	5.6	5.0	5.2	5.2	4.5	3.9	4.5	4.0	3.6	3.9	3.6
Three point loads (quarter points)	Each kN	3.7	3.3	3.5	3.5	3.0	2.6	3.0	2.7	2.4	2.6	2.4

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 11kN 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. Restraint point must support both top and bottom booms at restraint location.

Graph Summary of Allowable Working Loads for a Ladder Beam to BS EN 1999-1-1