ALANWHITEDESIGN
INSPIRED ENGINEERING

22126-15-001A

APOLLO SCAFFOLD SERVICES LTD

SCAFFOLD BEAMS

160MM LADDER BEAM

DESIGN CALCULATIONS

NOV 2023

REGISTERED IN SCOTLAND
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AWD016-05 Rev 5 by EMcG 17-01-2020

DOCUMENT REVISION HISTORY

REV.	DESCRIPTION	AUTHOR	DATE	CHECKED	APPROVED
A	Initial issue	PL	08-11-2023	ES	MR

TEMPORARY WORKS DESIGN CERTIFICATE

Project: Scaffold Beams

Client: Apollo Scaffold Services Ltd

Design Brief Issued: Yes

Design Brief Reference: Email

Does the design comply with the brief: Yes

Name	Paul Lynch
Title	Design Engineer
Signature	*Paul Lynch*
	To be signed by the Temporary Works Designer or other person authorised to sign on behalf of the organisation responsible for the Design of the Temporary Works.

Documents Produced
22126-15-001A

Notes:
Beam must be have chord restraints at 1.00m c/c.
Load must only be applied to node points.

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BRIEF

To prepare calculated values for the capacity of the Apollo 160mm Ladder Beam with horizontal restraints every 1.00m to BS EN 1999-1-1+A2.

LAYOUT

160mm Ladder Beam show below:

DESIGN STANDARDS USED

BS EN 1999-1-1 Design of Aluminium Structures – General rules

NA to BS EN 1999-1-1 UK National Annex to Design of Aluminium Structures – General rules

INFORMATION RECEIVED

3D CAD blocks 160mm Ladder Beam.dwg

LOADING

The beam will be analysed for 5No load combinations:

- UDL - 10kN/m applied over full length of beam
- Central Point Load - 10kN applied to central point of top boom
- Two Point Loads - 2No 10kN applied at third points of top boom
- Three Point Loads - 3No 10kN applied at quarter points of top boom
- End Shear - 10kN applied 1.00m from end support

NOTE: LOAD MUST ONLY BE APPLIED AT NODE POINTS.

STABILITY

Beams to be simply supported at each end with horizontal restraints at 1.00m centres.

ASSUMPTIONS

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

fo = 250N/mm²

fu = 290N/mm²

Load must only be applied at node points.

Beam must be restrained at 1.00m centres.

EXCLUSIONS

Spigot connections are not covered in this report. For spigot design see AWD Ref. Y0149-01-001A.

SUMMARY

Maximum Allowable Moment and Maximum Allowable Shear can be found in the Results Summary section of this report.

Test Results

	Span (m)		
	3	6	9
Allowable Moment	3.1	4.0	3.1
Allowable Shear (Load on Vertical)	4.2	4.1	4.1

Type of Load		Clear span (m)						
		3	4	5	6	7	8	9
Uniformly Distributed load	kN/m	2.8	2.1	1.5	0.9	0.7	0.5	0.3
Total UDL	kN	8.3	8.5	7.6	5.3	4.9	4.0	2.8
Single point load (mid Point)	kN	4.1	3.6	3.2	2.7	2.2	1.8	1.4
Two point loads (third points)	Each kN	3.1	2.7	2.4	2.0	1.7	1.4	1.0
Three point loads (quarter points)	Each kN	2.1	1.8	1.6	1.3	1.1	0.9	0.7

Notes:

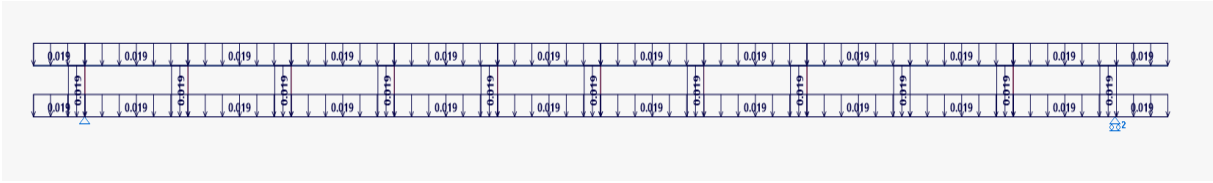
1. Above allowable loads may be increased by 1.11 for **wind loading only**
2. This table is provided as a guide only and assume all loads are applied at nodes. All scaffolds and structures should be checked by a qualified structural engineer.
3. Maximum capacity of a point load mid way between nodes 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 1.0m c/c
4. Factor of Safety = 1.65
5. Calculations as per BS EN 1999-1-2-A2
6. All allowable loads below take the self weight of the beam into account.

Load Cases

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

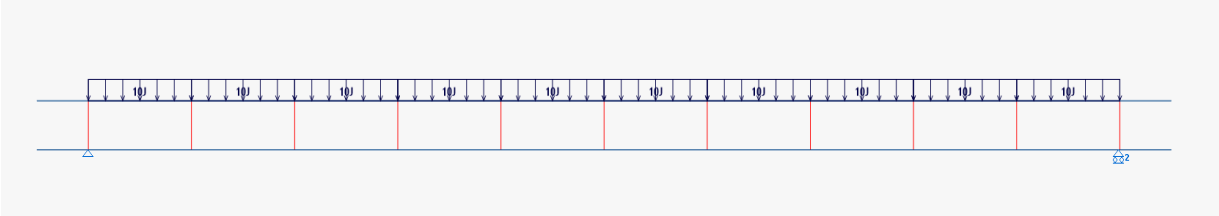
Load Case 1 **Self Weight**

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



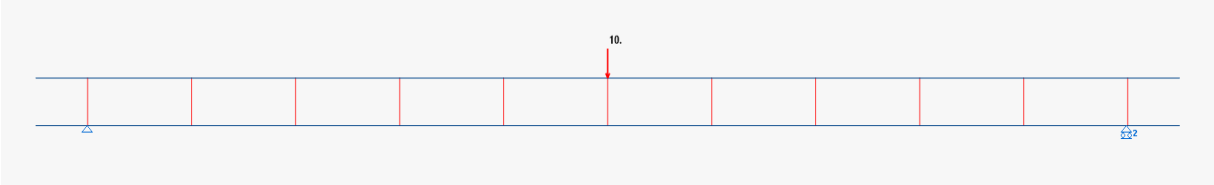
Load Case 2 **UDL**

10kN/m load applied to the top boom over full length of the Ladder Beam.
NOTE: Line load applied to model as joint loads at node points.



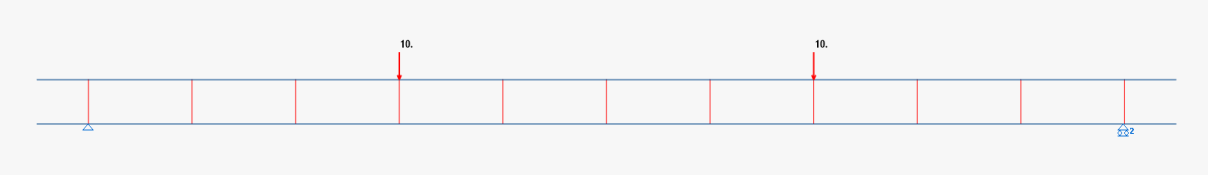
Load Case 3 **Central Point Load**

10kN Point Load Applied to Centre of each top boom of the Ladder Box Beam.



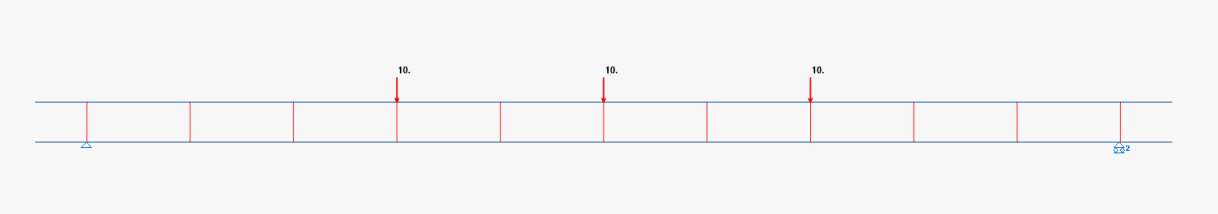
Load Case 4 **Two Point Loads**

10kN point loads applied at third points along each the top boom of the Ladder Beam.



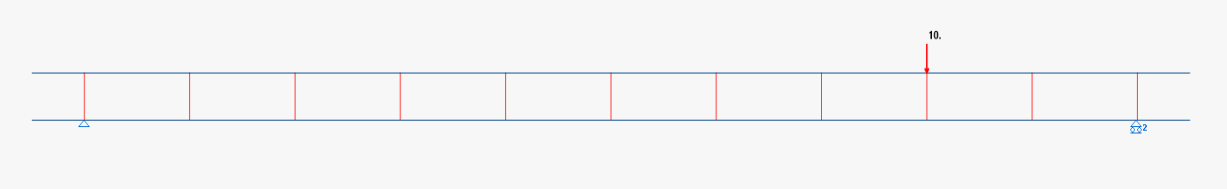
Load Case 5 **Three Point Loads**

10kN Point Loads applied at quarter points along each of the top booms of the Ladder Beam.



Load Case 6 **End Shear**

10kN point load applied 0.60m from support on the top boom of the Ladder Beam.



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:

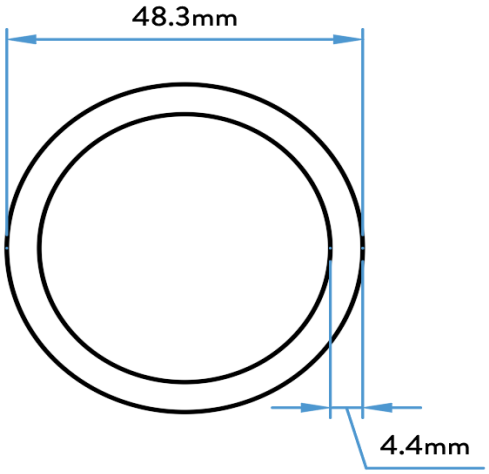
γ_D= 1.35

γ_L= 1.50

Main Boom Capacity
ø48.3mm x 4.4mm - 6082-T6

Alu. 6082-T6	$P_{o,haz}$ =	0.50	
	$P_{u,haz}$ =	0.64	
	f_o =	255	N/mm^2
	f_u =	295	N/mm^2

Class A Material



A=	607	mm^2
L =	1000	mm
k =	0.70	
L_{cr} =	700	mm
I=	147654	mm^4
W_{el}=	6114	mm^3
W_{pl}=	8254	mm^3
r_y=	15.6	mm

for slenderness	β=	b/t	b=	48.3 mm
	=	10.98	t =	4.4 mm
	ε=	sqrt(250/f_o)	f_o=	255 N/mm^2
	=	0.99		

Class A, without welds, Internal parts	β_1=	11ε
	=	11*1.00
	=	11.00
	>	10.98

Section is class 1

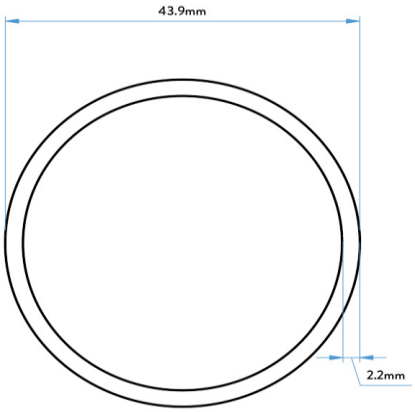
HAZ Length

Part perimeter weld at the joint, therefore part section is affected by HAZ.

As per BS EN 1999-1-1, for HAZ wall thickness factored by 0.50 (For $P_{o,haz}$)

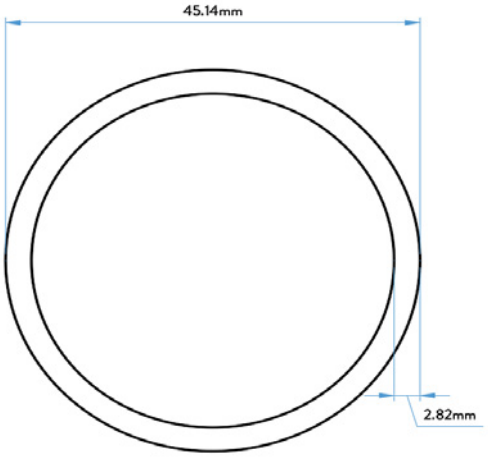
As per BS EN 1999-1-1, for HAZ wall thickness factored by 0.64 (For $P_{u,haz}$)

Po,haz HAZ Section Layout



A_{haz}=	288	mm^2
I=	62820	mm^4
W_{el}=	2862	mm^3
W_{pl}=	3864	mm^3

Pu,haz HAZ Section Layout



A_{haz}=	375	mm^2
I=	84308	mm^4
W_{el}=	3,735	mm^3
W_{pl}=	5,043	mm^3

Moment Capacity (6.2.5.1)

Non-HAZ

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

$\alpha = W_{pl}/W_{el}$ (Table 6.4)
$= 1.35$
$W_{el} = 6.11\ cm^3$
$f_o = 255\ N/mm^2$
$\gamma_{M1} = 1.1$ (6.1.3)

$= 1.35*6.11*255/1100$
$M_{c,Rd} = 1.91\ kNm$

HAZ

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

$W_{net} = W_{u\ eff}$
$= 3.74\ cm^3$
$f_u = 295\ N/mm^2$
$\gamma_{M2} = 1.25$ (6.1.3)

$= 3.74*295/1250$
$M_{u,Rd} = 0.88\ kNm$

$M_{Rd,x} = 0.88\ kNm$ lesser value of $M_{c,Rd}$ / $M_{u,Rd}$

Shear Capacity (6.2.6)

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

$A_v = nA_e$
$n = 0.60$
$A_e = 288\ mm^2$
$A_v = 0.6*288$
$A_v = 172.80\ mm^2$
$f_o = 255\ N/mm^2$
$\gamma_{M1} = 1.1$

$= 172.80*255/(SQRT(3)*1100)$
$V_{Rd} = 23.13\ kN$

Vertical Axial Comp Capacity

Without Weld

$N_{b,Rd} = kX A_{eff} f_o / \gamma_{M1}$ (6.3.1.1 (6.49a))

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

$E = 70{,}000$ N/mm^2
$I = 147{,}654$ mm^4
$L_{cr} = 700.00$ mm

$N_{cr} = (((PI()^2)*70000*147654))/((700^2))$
$= 208{,}183.80$ N

$\lambda = \sqrt{A_{eff} f_o / N_{cr}}$ (6.3.1.2)
$= 0.86$ $A_{eff} = 607$ 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
$\Phi = 0.95$

$X = 0.75$

$k = 1.00$ (no welds)

$N_{b,Rd} = 1.00*0.75*607*250/1100$
$= 104.84$ kN

Localised Weld

$N_{b,Rd} = X_{haz}\omega_{x,haz} A_{u,eff} f_u / \gamma_{M2}$ (6.3.1.1 (6.49b))

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

$E =$ 70,000 N/mm^2
$I =$ 147,654 mm^4
$L_{cr} =$ 700.00 mm

$N_{cr} =$ (((PI()^2)*70000*147654))/((700^2))
$=$ 208,183.80 N

$\lambda_{haz} = \sqrt{A_{u,eff} f_u / N_{cr}}$ (6.3.1.2)
$=$ 0.64

$A_{u,eff} =$ 375 mm^2

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

$\Phi = 0.5(1+\acute{\alpha}(\lambda-\lambda_o)+\lambda^2)$
$\acute{\alpha} =$ 0.20 Table 6.6
$\lambda_o =$ 0.10 Table 6.6
$\Phi =$ 0.76
$X_{haz} =$ 0.86

$\omega_{x,haz} = 1/X_{haz}+(1-X_{haz})\sin(PI()x_{s,haz}/L_{cr})$

For end results
$x_{s,haz} =$ 150 mm
$=$ 1.06

$N_{b,Rd} =$ 0.86*1.06*375*295/1250
$=$ 80.28 kN

Lesser Value= 80.28 kN

Axial Tension Capacity (6.2.3)

1. General yielding

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

$f_o =$ 255 N/mm^2
$A_g =$ A
$=$ 607 mm^2
$\gamma_{M1} =$ 1.1

$=$ 607*255/1100
$=$ 140.67 kN

2. Local failure

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

$f_u =$ 295 N/mm^2
$A_{u,eff} =$ 375 mm^2
$\gamma_{M1} =$ 1.25

$=$ 375*295/1250
$=$ 88.50 kN

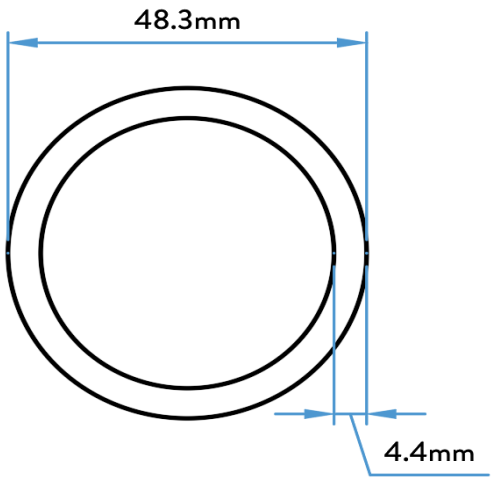
Lesser Value= 88.50 kN

Vertical Boom Capacity
ø48.3mm x 4.4mm - 6082-T6

Alu. 6082-T6

$P_{o,haz}$ =	0.50	
$P_{u,haz}$ =	0.64	
f_o =	255	N/mm^2
f_u =	295	N/mm^2

Class A Material



A=	607	mm^2
L =	160	mm
k =	0.70	
L_{cr} =	112	mm
I=	147654	mm^4
W_{el}=	6114	mm^3
W_{pl}=	8254	mm^3
r_y=	15.6	mm

for slenderness

β=	b/t	b=	48.3 mm
=	10.98	t =	4.4 mm
ε=	sqrt(250/f_o)	f_o=	255 N/mm^2
=	0.99		

Class A, without welds, Internal parts

β_1=	11ε
=	11*1.00
=	11.00
>	10.98

Section is class 1

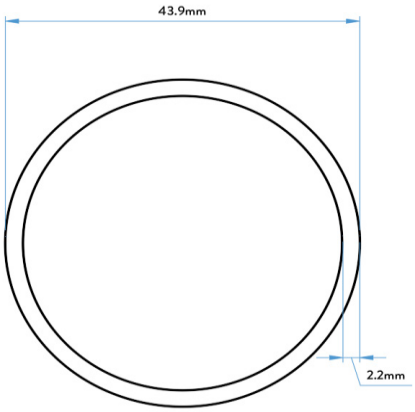
HAZ Length

Part perimeter weld at the joint, therefore part section is affected by HAZ.

As per BS EN 1999-1-1, for HAZ wall thickness factored by 0.50 (For $P_{o,haz}$)

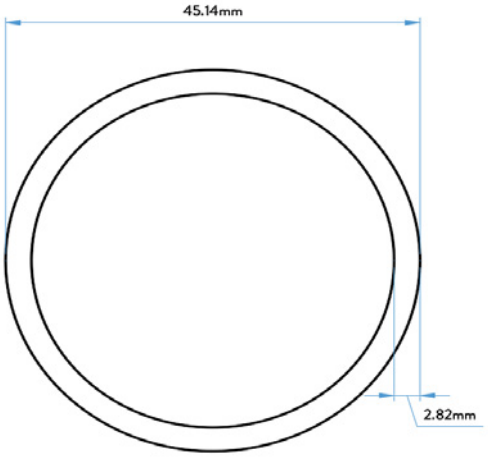
As per BS EN 1999-1-1, for HAZ wall thickness factored by 0.64 (For $P_{u,haz}$)

Po,haz HAZ Section Layout



A_{haz}=	288	mm^2
I=	62820	mm^4
W_{el}=	2862	mm^3
W_{pl}=	3864	mm^3

Pu,haz HAZ Section Layout



A_{haz}=	375	mm^2
I=	84308	mm^4
W_{el}=	3,735	mm^3
W_{pl}=	5,043	mm^3

Moment Capacity (6.2.5.1)

Non-HAZ

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

$\alpha = W_{pl}/W_{el}$ (Table 6.4)
$= 1.35$
$W_{el} = 6.11\ cm^3$
$f_o = 255\ N/mm^2$
$\gamma_{M1} = 1.1$ (6.1.3)

$= 1.35*6.11*255/1100$
$M_{c,Rd} = 1.91\ kNm$

HAZ

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

$W_{net} = W_{u\ eff}$
$= 3.74\ cm^3$
$f_u = 295\ N/mm^2$
$\gamma_{M2} = 1.25$ (6.1.3)

$= 3.74*295/1250$
$M_{u,Rd} = 0.88\ kNm$

$M_{Rd,x} = 0.88\ kNm$ lesser value of $M_{c,Rd}$ / $M_{u,Rd}$

Shear Capacity (6.2.6)

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

$A_v = nA_e$
$n = 0.60$
$A_e = 288\ mm^2$
$A_v = 0.6*288$
$A_v = 172.80\ mm^2$
$f_o = 255\ N/mm^2$
$\gamma_{M1} = 1.1$

$= 172.80*255/(SQRT(3)*1100)$
$V_{Rd} = 23.13\ kN$

Vertical Axial Comp Capacity

Without Weld

$N_{b,Rd} = kX A_{eff} f_o / \gamma_{M1}$ (6.3.1.1 (6.49a))

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

$E =$ 70,000 N/mm^2
$I =$ 147,654 mm^4
$L_{cr} =$ 112.00 mm

$N_{cr} = (((PI()^2)*70000*147654))/((213.50^2))$
$= 8,132,179.51$ N

$\lambda = \sqrt{A_{eff} f_o / N_{cr}}$ (6.3.1.2)
$= 0.14$ $A_{eff} =$ 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
$\Phi =$ 0.51

$X =$ 0.99

$k =$ 1.00 (no welds)

$N_{b,Rd} = 1.00*0.58*607*250/1100$
$= 139.59$ kN

Localised Weld

$N_{b,Rd} = X_{haz}\omega_{x,haz} A_{u,eff} f_u / \gamma_{M2}$ (6.3.1.1 (6.49b))

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

$E =$ 70,000 N/mm^2
$I =$ 147,654 mm^4
$L_{cr} =$ 112.00 mm

$N_{cr} = (((PI()^2)*70000*147654))/((213.50^2))$
$= 8,132,179.51$ N

$\lambda_{haz} = \sqrt{A_{u,eff} f_u / N_{cr}}$ (6.3.1.2)
$= 0.11$

$A_{u,eff} =$ 375 mm^2

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

$\Phi = 0.5(1+\acute{\alpha}(\lambda-\lambda_o)+\lambda^2)$
$\acute{\alpha} =$ 0.20 Table 6.6
$\lambda_o =$ 0.10 Table 6.6
$\Phi =$ 0.51
$X_{haz} = 1.00$

$\omega_{x,haz} = 1/X_{haz}+(1-X_{haz})\sin(PI()x_{s,haz}/lcr)$

For end results
$x_{s,haz} =$ 0
$= 1.00$

$N_{b,Rd} = 1.00*1.00*375*295/1250$
$= 88.50$ kN

Lesser Value= 88.50 kN

Axial Tension Capacity (6.2.3)

1. General yielding

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

$f_o =$ 255 N/mm^2

$A_g =$ A

$=$ 607 mm^2

$\gamma_{M1} =$ 1.1

$=$ 607*255/1100

$=$ 140.67 kN

2. Local failure

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

$f_u =$ 295 N/mm^2

$A_{u,eff} =$ 375 mm^2

$\gamma_{M1} =$ 1.25

$=$ 375*295/1250

$=$ 88.50 kN

Lesser Value= 88.50 kN

3m - Load Comb.1 UDL load

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.88	1.60	0.55
	Shear	V_{Rd}	23.13	10.37	2.23
	Tension	$N_{o,Rd}$	88.50	140.79	0.63
	Compression	$N_{b,Rd}$	80.28	140.79	0.57
	Deflection	d	30.00	42.96	0.70
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.31
Vertical	Moment	$M_{c,Rd}$	0.88	2.44	0.36
	Shear	V_{Rd}	23.13	43.46	0.53
	Tension	$N_{o,Rd}$	88.50	0.00	88500.00
	Compression	$N_{b,Rd}$	88.50	12.60	7.02
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.35
				Factor	**0.31**

Max Moment= $ML^2/8$

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.31
= 4.61 kN

so maximum moment is as above

Ultimate Mu= Wf*3^2/8
= (4.61*3^2)/8
= 5.18 kNm

and for allowable value

allowable max moment= 5.18/1.50
= 3.46 kNm

Moment values	**Ultimate**	**5.18 kNm**
	Allowable	**3.46 kNm**

3m - Load Comb. 2 Point load

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.88	1.07	0.83
	Shear	V_{Rd}	23.13	3.81	6.08
	Tension	$N_{o,Rd}$	88.50	83.77	1.06
	Compression	$N_{b,Rd}$	80.28	83.77	0.96
	Deflection	d	30.00	23.73	1.26
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.49
Vertical	Moment	$M_{c,Rd}$	0.88	1.06	0.83
	Shear	V_{Rd}	23.13	18.99	1.22
	Tension	$N_{o,Rd}$	88.50	0.01	11062.50
	Compression	$N_{b,Rd}$	88.50	7.44	11.89
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.80
				Factor	**0.49**

Max Moment= ML/4

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.49
= 7.32 kN

so maximum moment is as above

Ultimate Mu= Wf*3/4
= (7.32*3)/4
= 5.49 kNm

and for allowable value

allowable max moment= 5.49/1.50
= 3.66 kNm

Moment values	**Ultimate**	**5.49 kNm**
	Allowable	**3.66 kNm**

3m - Load Comb. 3

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.88	1.68	0.52
	Shear	V_{Rd}	23.13	7.57	3.06
	Tension	$N_{o,Rd}$	88.50	114.06	0.78
	Compression	$N_{b,Rd}$	80.28	114.06	0.70
	Deflection	d	30.00	35.71	0.84
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.33
Vertical	Moment	$M_{c,Rd}$	0.88	2.03	0.43
	Shear	V_{Rd}	23.13	36.51	0.63
	Tension	$N_{o,Rd}$	88.50	0.02	5531.25
	Compression	$N_{b,Rd}$	88.50	7.53	11.75
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.43
				Factor	**0.33**

Max Moment= ML/3

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.33
= 4.96 kN

so maximum moment is as above

Ultimate Mu= Wf*3/3
= (4.96*3)/3
= 4.96 kNm

and for allowable value

allowable max moment= 4.96/1.50
= 3.31 kNm

Moment values	**Ultimate**	**4.96 kNm**
	Allowable	**3.31 kNm**

3m - Load Comb. 4

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.88	2.46	0.36
	Shear	V_{Rd}	23.13	11.33	2.04
	Tension	$N_{o,Rd}$	88.50	197.27	0.45
	Compression	$N_{b,Rd}$	80.28	197.27	0.41
	Deflection	d	30.00	59.25	0.51
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.21
Vertical	Max Moment	$M_{c,Rd}$	0.88	3.08	0.29
	Shear	V_{Rd}	23.13	54.86	0.42
	Tension	$N_{o,Rd}$	88.50	0.00	88500.00
	Compression	$N_{b,Rd}$	88.50	11.27	7.85
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.28
				Factor	**0.21**

Max Moment= ML/2

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.21
= 3.14 kN

so maximum moment is as above

Ultimate Mu= Wf*3/2
= (3.14*3)/2
= 4.71 kNm

and for allowable value

allowable max moment= 4.71/1.50
= 3.14 kNm

Moment values	**Ultimate**	**4.71 kNm**
	Allowable	**3.14 kNm**

3m - Load Comb. 5 End Shear

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Max Moment	$M_{c,Rd}$	0.88	1.23	0.72
	Shear	V_{Rd}	23.13	6.07	3.81
	Tension	$N_{o,Rd}$	88.50	55.22	1.60
	Compression	$N_{b,Rd}$	80.28	55.22	1.45
	Deflection	d	30.00	13.29	2.26
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.53
Vertical	Max Moment	$M_{c,Rd}$	0.88	1.53	0.58
	Shear	V_{Rd}	23.13	27.28	0.85
	Tension	$N_{o,Rd}$	88.50	0.01	9833.33
	Compression	$N_{b,Rd}$	88.50	7.44	
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.57
				Factor	**0.53**

Max Shear Rb= W*2.4/3

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.53
= 7.90 kN

so maximum moment is as above

Ultimate Qu= Wf*2.4/3
= (7.90*2.4)/3
= 6.32 kN

and for allowable value

allowable max shear= 6.32/1.50
= 4.22 kN

Shear values	**Ultimate**	**6.32 kN**
	Allowable	**4.22 kN**

3m Span Results

160mm LADDER BEAM			
Loadcase No.		Ultimate Moment	Allowable Moment
1	UDL	5.18	3.46
2	Point	5.49	3.66
3	Third	4.96	3.31
4	Quarter	4.71	3.14

Loadcase No.		Ultimate Shear	Allowable Shear
5	End Shear	6.32	4.22

Max Allowable Moment = 3.10 kNm

Max Allowable Shear = 4.20 kN

6m - Load Comb.1 UDL load

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.88	3.81	0.23
	Shear	V_{Rd}	23.13	21.88	1.06
	Tension	$N_{o,Rd}$	88.50	576.09	0.15
	Compression	$N_{b,Rd}$	80.28	576.09	0.14
	Deflection	d	60.00	587.18	0.10
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.09
Vertical	Moment	$M_{c,Rd}$	0.88	5.55	0.16
	Shear	V_{Rd}	23.13	98.92	0.23
	Tension	$N_{o,Rd}$	88.50	0.00	88500.00
	Compression	$N_{b,Rd}$	88.50	24.06	3.68
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.16
				Factor	**0.09**

Max Moment= $ML^2/8$

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.09
= 1.41 kN

so maximum moment is as above

Ultimate Mu= Wf*6^2/8
= (1.41*6^2)/8
= 6.35 kNm

and for allowable value

allowable max moment= 6.35/1.50
= 4.24 kNm

Moment values	**Ultimate**	**6.35 kNm**
	Allowable	**4.24 kNm**

6m - Load Comb. 2 Point load

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.88	1.49	0.59
	Shear	V_{Rd}	23.13	3.85	6.00
	Tension	$N_{o,Rd}$	88.50	180.28	0.49
	Compression	$N_{b,Rd}$	80.28	180.28	0.45
	Deflection	d	60.00	158.38	0.38
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.28
Vertical	Moment	$M_{c,Rd}$	0.88	1.08	0.82
	Shear	V_{Rd}	23.13	19.27	1.20
	Tension	$N_{o,Rd}$	88.50	0.01	9833.33
	Compression	$N_{b,Rd}$	88.50	7.44	11.89
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.79
				Factor	**0.28**

Max Moment= ML/4

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.28
= 4.16 kN

so maximum moment is as above

Ultimate Mu= Wf*6/4
= (4.16*6)/4
= 6.24 kNm

and for allowable value

allowable max moment= 6.24/1.50
= 4.16 kNm

Moment values	**Ultimate**	**6.24 kNm**
	Allowable	**4.16 kNm**

6m - Load Comb. 3

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.88	2.19	0.40
	Shear	V_{Rd}	23.13	7.61	3.04
	Tension	$N_{o,Rd}$	88.50	229.74	0.39
	Compression	$N_{b,Rd}$	80.28	229.74	0.35
	Deflection	d	60.00	245.25	0.24
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.20
Vertical	Moment	$M_{c,Rd}$	0.88	2.14	0.41
	Shear	V_{Rd}	23.13	38.20	0.61
	Tension	$N_{o,Rd}$	88.50	0.01	9833.33
	Compression	$N_{b,Rd}$	88.50	7.58	11.68
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.41
				Factor	**0.20**

Max Moment= ML/3

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.20
= 3.07 kN

so maximum moment is as above

Ultimate Mu= Wf*6/3
= (3.07*6)/3
= 6.14 kNm

and for allowable value

allowable max moment= 6.14/1.50
= 4.10 kNm

Moment values	**Ultimate**	**6.14 kNm**
	Allowable	**4.10 kNm**

6m - Load Comb. 4

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.88	2.96	0.30
	Shear	V_{Rd}	23.13	11.37	2.03
	Tension	$N_{o,Rd}$	88.50	369.82	0.24
	Compression	$N_{b,Rd}$	80.28	369.82	0.22
	Deflection	d	60.00	368.46	0.16
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.14
Vertical	Max Moment	$M_{c,Rd}$	0.88	3.19	0.28
	Shear	V_{Rd}	23.13	56.98	0.41
	Tension	$N_{o,Rd}$	88.50	0.01	8850.00
	Compression	$N_{b,Rd}$	88.50	11.32	7.82
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.27
				Factor	**0.14**

Max Moment= ML/2

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.14
= 2.05 kN

so maximum moment is as above

Ultimate Mu= Wf*6/2
= (2.05*6)/2
= 6.15 kNm

and for allowable value

allowable max moment= 6.15/1.50
= 4.10 kNm

Moment values	**Ultimate**	**6.15 kNm**
	Allowable	**4.10 kNm**

6m - Load Comb. 5 End Shear

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Max Moment	$M_{c,Rd}$	0.88	1.38	0.64
	Shear	V_{Rd}	23.13	6.87	3.37
	Tension	$N_{o,Rd}$	88.50	65.28	1.36
	Compression	$N_{b,Rd}$	80.28	65.28	1.23
	Deflection	d	60.00	48.88	1.23
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.46
Vertical	Max Moment	$M_{c,Rd}$	0.88	1.74	0.51
	Shear	V_{Rd}	23.13	31.12	0.74
	Tension	$N_{o,Rd}$	88.50	0.01	9833.33
	Compression	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,}$	88.50	7.44	11.90
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.50
				Factor	**0.46**

Max Shear Rb= W*5.4/6

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.46
= 6.94 kN

so maximum moment is as above

Ultimate Qu= Wf*5.4/6
= (6.94*5.4)/6
= 6.25 kN

and for allowable value

allowable max shear= 6.25/1.50
= 4.16 kN

Shear values	**Ultimate**	**6.25 kN**
	Allowable	**4.16 kN**

6m Span Results

160mm LADDER BEAM			
Loadcase No.		Ultimate Moment	Allowable Moment
1	UDL	6.35	4.24
2	Point	6.24	4.16
3	Third	6.14	4.10
4	Quarter	6.15	4.10

Loadcase No.		Ultimate Shear	Allowable Shear
5	End Shear	6.25	4.16

Max Allowable Moment = 4.00 kNm

Max Allowable Shear = 4.10 kN

9m - Load Comb.1 UDL load

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.88	6.96	0.13
	Shear	V_{Rd}	23.13	33.40	0.69
	Tension	$N_{o,Rd}$	88.50	1301.59	0.07
	Compression	$N_{b,Rd}$	80.28	1301.59	0.06
	Deflection	d	90.00	2874.40	0.03
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.04
Vertical	Moment	$M_{c,Rd}$	0.88	8.65	0.10
	Shear	V_{Rd}	23.13	154.38	0.15
	Tension	$N_{o,Rd}$	88.50	0.00	88500.00
	Compression	$N_{b,Rd}$	88.50	35.51	2.49
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.10
				Factor	**0.03**

Max Moment= $ML^2/8$

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.03
= 0.47 kN

so maximum moment is as above

Ultimate Mu= Wf*9^2/8
= (0.47*9^2)/8
= 4.76 kNm

and for allowable value

allowable max moment= 4.76/1.50
= 3.17 kNm

Moment values	**Ultimate**	**4.76 kNm**
	Allowable	**3.17 kNm**

9m - Load Comb. 2 Point load

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.88	1.91	0.46
	Shear	V_{Rd}	23.13	3.90	5.93
	Tension	$N_{o,Rd}$	88.50	277.95	0.32
	Compression	$N_{b,Rd}$	80.28	277.95	0.29
	Deflection	d	90.00	516.95	0.17
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.19
Vertical	Moment	$M_{c,Rd}$	0.88	1.09	0.81
	Shear	V_{Rd}	23.13	19.50	1.19
	Tension	$N_{o,Rd}$	88.50	0.01	9833.33
	Compression	$N_{b,Rd}$	88.50	7.44	11.89
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.78
				Factor	**0.17**

Max Moment= ML/4

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.17
= 2.61 kN

so maximum moment is as above

Ultimate Mu= Wf*9/4
= (2.61*9)/4
= 5.88 kNm

and for allowable value

allowable max moment= 5.88/1.50
= 3.92 kNm

Moment values	**Ultimate**	**5.88 kNm**
	Allowable	**3.92 kNm**

9m - Load Comb. 3

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.88	2.69	0.33
	Shear	V_{Rd}	23.13	7.66	3.02
	Tension	$N_{o,Rd}$	88.50	346.37	0.26
	Compression	$N_{b,Rd}$	80.28	346.37	0.23
	Deflection	d	90.00	804.96	0.11
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.15
Vertical	Moment	$M_{c,Rd}$	0.88	2.15	0.41
	Shear	V_{Rd}	23.13	38.45	0.60
	Tension	$N_{o,Rd}$	88.50	0.01	9833.33
	Compression	$N_{b,Rd}$	88.50	7.62	11.61
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.40
				Factor	**0.11**

Max Moment= ML/3

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.11
= 1.68 kN

so maximum moment is as above

Ultimate Mu= Wf*9/3
= (1.68*9)/3
= 5.03 kNm

and for allowable value

allowable max moment= 5.03/1.50
= 3.35 kNm

Moment values	**Ultimate**	**5.03 kNm**
	Allowable	**3.35 kNm**

9m - Load Comb. 4

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Moment	$M_{c,Rd}$	0.88	3.47	0.25
	Shear	V_{Rd}	23.13	11.42	2.03
	Tension	$N_{o,Rd}$	88.50	543.30	0.16
	Compression	$N_{b,Rd}$	80.28	543.30	0.15
	Deflection	d	90.00	1165.30	0.08
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.10
Vertical	Max Moment	$M_{c,Rd}$	0.88	3.21	0.27
	Shear	V_{Rd}	23.13	57.39	0.40
	Tension	$N_{o,Rd}$	88.50	0.01	8045.45
	Compression	$N_{b,Rd}$	88.50	11.36	7.79
	Combined	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.27
				Factor	**0.08**

Max Moment= ML/2

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.08
= 1.16 kN

so maximum moment is as above

Ultimate Mu= Wf*9/2
= (1.16*9)/2
= 5.21 kNm

and for allowable value

allowable max moment= 5.21/1.50
= 3.48 kNm

Moment values	**Ultimate**	**5.21 kNm**
	Allowable	**3.48 kNm**

9m - Load Comb. 5 End Shear

Element	Action	Formula	Ultimate	Calculated	Factor
Boom	Max Moment	$M_{c,Rd}$	0.88	1.43	0.62
	Shear	V_{Rd}	23.13	7.16	3.23
	Tension	$N_{o,Rd}$	88.50	69.02	1.28
	Compression	$N_{b,Rd}$	80.28	69.02	1.16
	Deflection	d	90.00	114.22	0.79
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.44
Vertical	Max Moment	$M_{c,Rd}$	0.88	1.82	0.48
	Shear	V_{Rd}	23.13	32.55	0.71
	Tension	$N_{o,Rd}$	88.50	0.01	9833.33
	Compression	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,}$	88.50	7.44	11.90
	Combined Axial	$(N_{ed}/N_{Rd})^{1.3} + [(M_{ed,x}/M_{rd,x})^{1.7}]^{0.6} < 1.0$		1.00	0.48
				Factor	**0.44**

Max Shear Rb= W*8.4/9

so for ultimate condition

W= 1.50*10.00
15.00 kN

apply factor from above

Wf= 15.00*0.44
= 6.64 kN

so maximum moment is as above

Ultimate Qu= Wf*8.4/9
= (6.64*8.4)/9
= 6.20 kN

and for allowable value

allowable max shear= 6.20/1.50
= 4.13 kN

Shear values	**Ultimate**	**6.20 kN**
	Allowable	**4.13 kN**

9m Span Results

160mm LADDER BEAM			
Loadcase No.		Ultimate Moment	Allowable Moment
1	UDL	4.76	3.17
2	Point	5.88	3.92
3	Third	5.03	3.35
4	Quarter	5.21	3.48

Loadcase No.		Ultimate Shear	Allowable Shear
5	End Shear	6.20	4.13

Max Allowable Moment = 3.10 kNm

Max Allowable Shear = 4.10 kN

Test Results

	Span (m)		
	3	6	9
Allowable Moment	3.1	4.0	3.1
Allowable Shear (Load on Vertical)	4.2	4.1	4.1

Allowable loads for load distributions from results

Type of Load	Clear span (m)			
		3	6	9
Uniformly Distributed load	kN/m	2.8	0.9	0.3
Total UDL	kN	8.3	5.3	2.8
Single point load (mid point)	kN	4.1	2.7	1.4
Two point loads (third points)	Each kN	3.1	2.0	1.0
Three point loads (quarter points)	Each kN	2.1	1.3	0.7

		3	6	9
Uniformly Distributed load	kN/m	*2.8*	*1.4*	*0.9*
Total UDL	kN	*8.4*	*8.2*	*8.2*
Single point load (mid point)	kN	*8.4*	*8.2*	*8.2*
Two point loads (third points)	Each kN	*4.2*	*4.1*	*4.1*
Three point loads (quarter points)	Each kN	*2.8*	*2.73*	*2.73*

Type of Load		Clear span (m)		
		3	6	9
Uniformly Distributed load	kN/m	2.8	0.9	0.3
Total UDL	kN	8.3	5.3	2.8
Single point load (mid Point)	kN	4.1	2.7	1.4
Two point loads (third points)	Each kN	3.1	2.0	1.0
Three point loads (quarter points)	Each kN	2.1	1.3	0.7

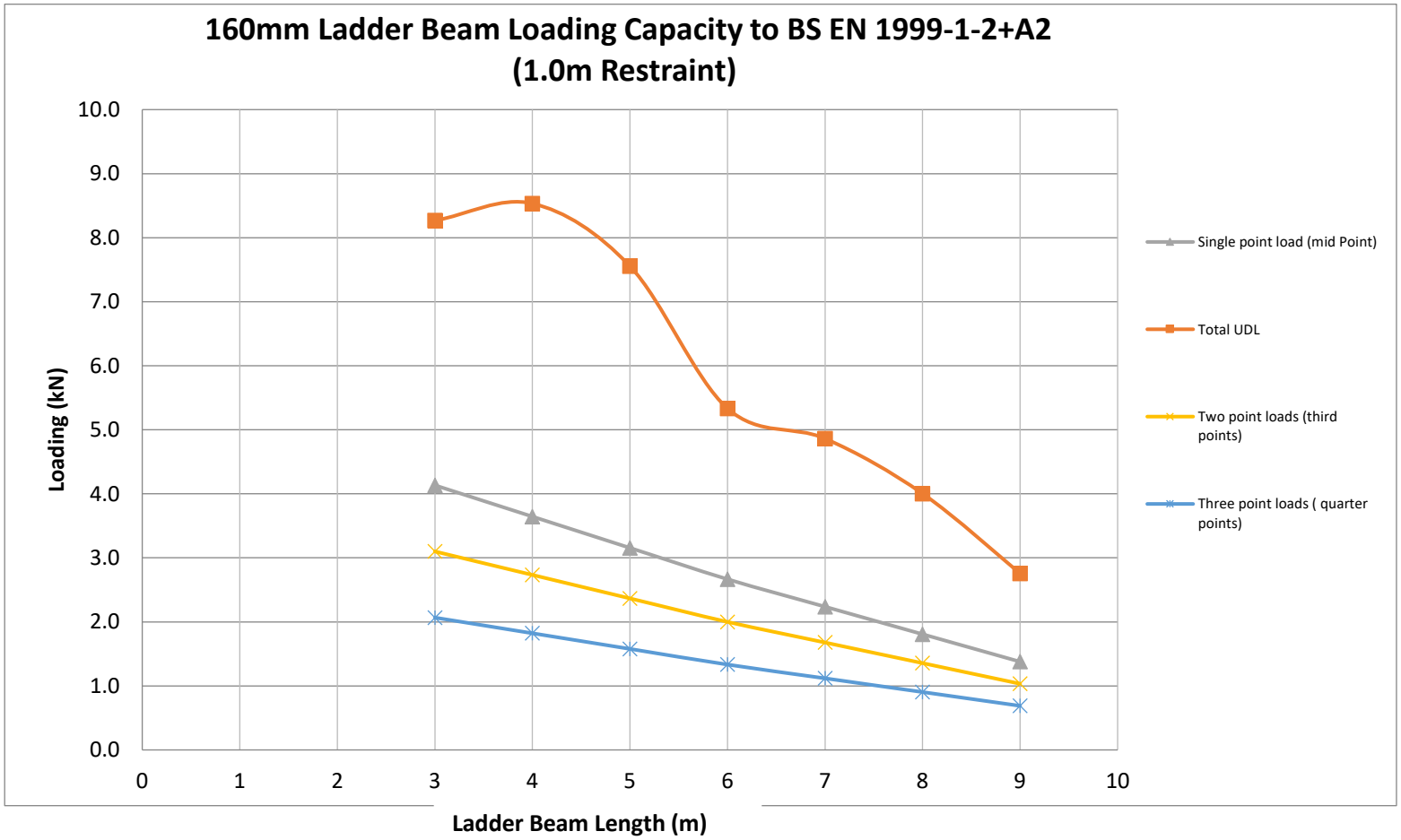
Extrapolated Allowable loads for load distributions

Type of Load		Clear span (m)						
		3	4	5	6	7	8	9
Uniformly Distributed load	kN/m	2.8	2.1	1.5	0.9	0.7	0.5	0.3
Total UDL	kN	8.3	8.5	7.6	5.3	4.9	4.0	2.8
Single point load (mid Point)	kN	4.1	3.6	3.2	2.7	2.2	1.8	1.4
Two point loads (third points)	Each kN	3.1	2.7	2.4	2.0	1.7	1.4	1.0
Three point loads (quarter points)	Each kN	2.1	1.8	1.6	1.3	1.1	0.9	0.7

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.
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 1.0m c/c
4. Factor of Safety = 1.65
5. Calculations as per BS EN 1999-1-2-A2
6. All allowable loads below take the self weight of the beam into account.

Graph Summary of Allowable Working Loads for a 160mm Ladder Beam to BS EN 1999-1-2+A2



Results Summary

Type of Load		Clear span (m)						
		3	4	5	6	7	8	9
Uniformly Distributed load	kN/m	2.8	2.1	1.5	0.9	0.7	0.5	0.3
Total UDL	kN	8.3	8.5	7.6	5.3	4.9	4.0	2.8
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Three point loads (quarter points)	Each kN	2.1	1.8	1.6	1.3	1.1	0.9	0.7

	Span (m)		
	3	6	9
Allowable Moment	3.1	4.0	3.1
Allowable Shear (Load on Vertical)	4.2	4.1	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.
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 1.0m c/c
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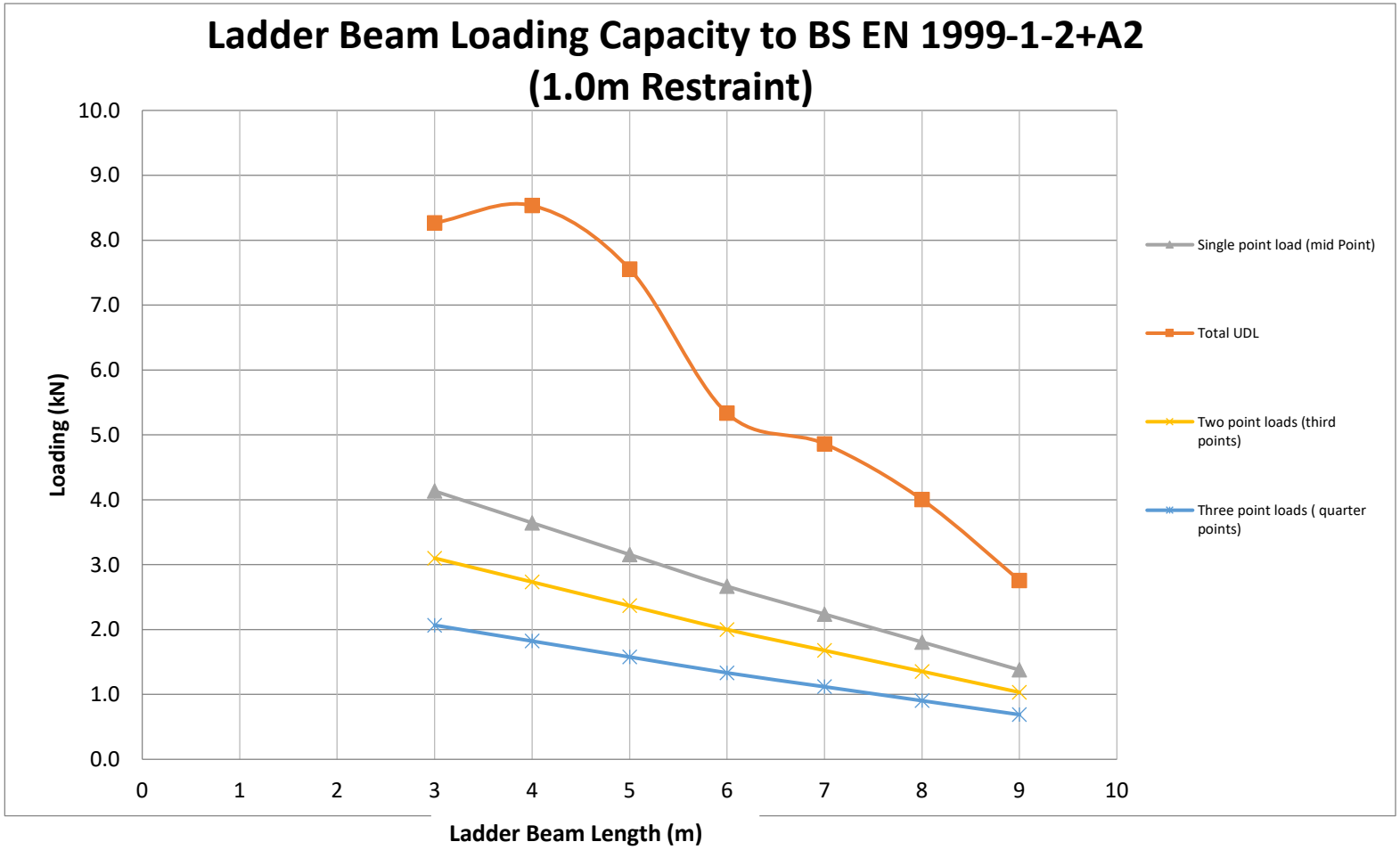


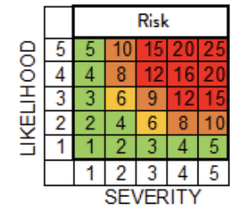
Client: Apollo Scaffold Services Ltd

Project: Scaffold Beams **Job No:** 22126-15 **By:** pl

Element: Designers Risk Assessment **Doc No:** 001A **Checked:** es **Date:** Wednesday Nov 08, 2023

Impact:	Probability:
1: Nil or slight injury / illness, property damage or environmental issue.	1 - Highly Unlikely
2: Minor injury / illness, property damage or environmental issue.	2 - Unlikely
3: Moderate injury or illness, property damage or environmental issue.	3 - Possible
4: Major injury or illness, property damage or environmental issue.	4 - Likely
5: Fatal or long term disabling injury or illness, property damage or environmental issue.	5 - Highly Likely

Risk type:	
Design	D
Construction	C
Operational	O
Decomissioning	D
-	-

Risk Rating	
Risk Rating System:	
Where the rating is 5 or less, no further action is required.	
Where the rating is 6 or more, the risk is unacceptable and control measures are required.	

Ref No	Risk Type	Activity / Element	Potential Hazard	Population at Risk	Prob	Imp	Risk Rating	Action at Design Stage	Prob	Imp	Risk Rating	Residual Risk	Residual Risk Description	Notes
1	D	Member Failure	Failure of beam due to insufficient member capacity.	operative_contractors	3	5	15	All member capacities have been calculated as per the requirements detailed in BS EN 1999-1-1.	1	5	5	N		
2	D	Beam Failure	Failure of beam due to incorrect horizontal restraint locations.	operative_contractors	3	5	15	Beam has been checked with 1.00m chord restraints.	3	5	15	Y	Client to ensure beam is horizontally restrained at 1.00m centres prior to loadings.	

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