X0224-001A
APOLLO CRADLES LTD
LATTICE BEAM BOX LIFTING RIG
DESIGN CHECK CALCULATIONS

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

Malachy Ryan B.Eng, M.Sc., C.Eng., M.I.C.E.

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17-19 Hill Street
Kilmarnock
KA3 1HA
Tel:01563 594 621
Fax:01563 593 056
enquiry@alanwhitedesign.com

Document Revision History

Revision	Description	Author	Revision Date	Checked
A	Initial Issue	LJB	09/11/17	MMR

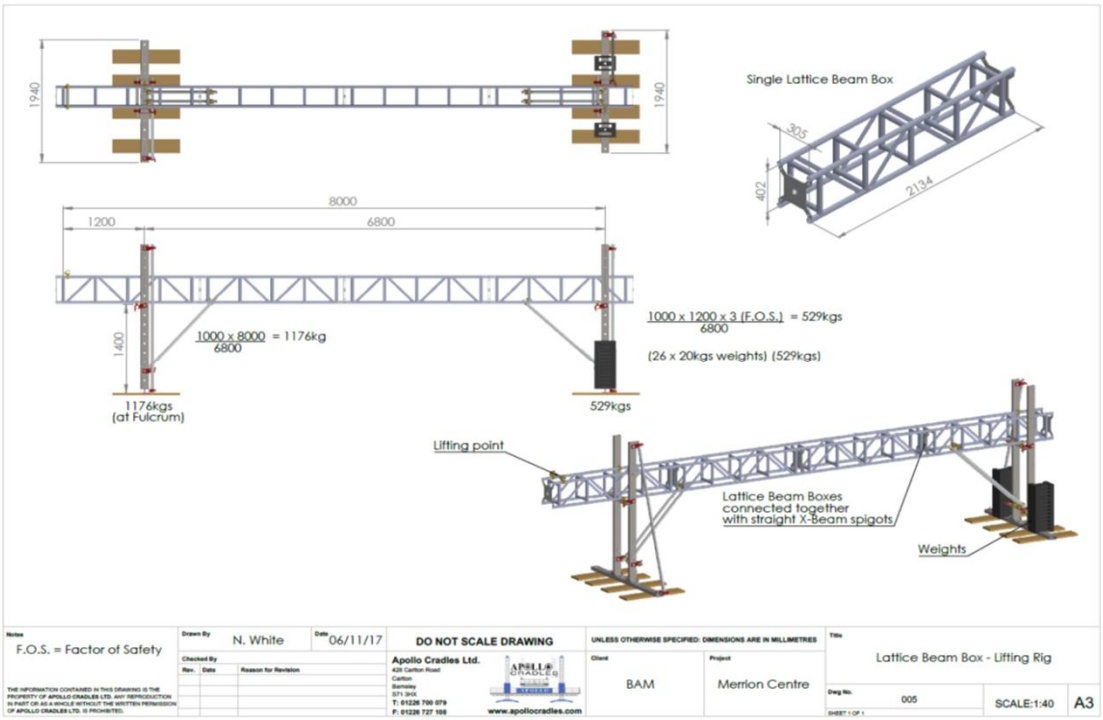
Brief

To produce design check calculations for an apollo lattice beam box lifting rig, for Apollo Cradles Ltd.

The rig is constructed from standard scaffold components, Apollo Lattice beam box, GKN legs and scaffold tubes.

Design check is only valid for the support frame, permanent structure is checked by others.

Layout



Design

Design of steel structures	EN 1993-1-1
Technical guidance	TG20:13
Suspended Access	EN 1808

Design assumptions

Scaffold components must be as per TG20:13.

GKN steelwork grade must be S355.

This design does not include a check of the existing structure.

A notional horizontal load of 10% of vertical load is included.

Client to provide 529kg of kentledge at the rear of the rig.

Lattice beams are connected with spigots.

Wind Loading

Wind calculation procedures are taken from the European standards:

Eurocode 1 Actions on structures - Wind	BS EN 1991-1-4
NA: Actions on Structures - Wind	NA BS EN 1991-1-4
Safety Requirements on Suspended Access Equipment	BS EN 1808

Working Wind Loading

Maximum wind pressure applied at working wind speed is:

Basic Wind Speed	V_b=	14.00	m/s	(BS EN 1808 T.6)
Dynamic Wind Pressure	q_b=	$k*V_e^2$		k=0.613
	=	0.12	kN/m^2	

Storm Wind Loading

Maximum wind pressure applied at storm wind speed is:

Basic Wind Speed	V_b=	36.00	m/s	(BS EN 1808 T.7)
Dynamic Wind Pressure	q_b=	$k*V_e^2$		k=0.613
	=	0.79	kN/m^2	

Applied Wind Pressure

The wind pressure is applied to the horizontal members of the lattice beam.

Largest Horizontal Member =	450	mm	
C_{pe} =	1		(Conservative)
Solidity =	0.25	%	

Applied Working Wind Pressure = 0.12*0.45*1.00*0.25
= 0.01 kN/m

Applied Storm Wind Pressure = 0.79*0.45*1.00*0.25
= 0.09 kN/m

Scaffold Tube Capacity

Scaffold tube capacity is taken from TG20 Table C.1 & C.2:

Safe Working Moment = 1.33 kNm

Safe Working Shear Force = 29.20 kN

Safe Working Axial Force = 8.70 kN (L_{eff} = 2500mm)

Safe working values are reduced by a factor of 1.65 in TG20 therefore the ultimate capacities are as follows:

Ultimate Moment = 1.33*1.65
= 2.19 kNm

Ultimate Shear Force = 29.20*1.65
= 48.18 kN

Ultimate Axial Force = 8.70*1.65
= 14.36 kN

Lattice Beam Capacity

Lattice Beam capacity is taken from AWD Document S0072-001:

Lattice Beam Allowable Moment = 16.20 kNm

Safe Working Shear Force = 15.80 kN

Safe working values are reduced by a factor of 1.65 in AWD Document therefore the ultimate capacities are as follows:

Ultimate Allowable Moment = 26.73 kNm
2No Lattice Beams = 53.46 kNm

Ultimate Safe Working Shear = 26.07 kN
2No Lattice Beams = 52.14 kN

Class A Coupler

Class A coupler capacity is taken from TG20 Table 5.15:

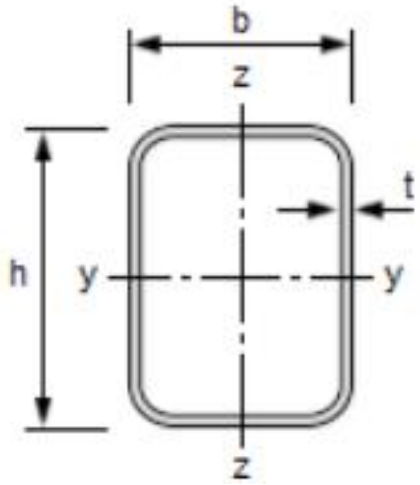
Class A Coupler SWL = 6.10 kN

Safe working values are reduced by a factor of 1.50 in TG20 T5.15 therefore the ultimate capacities are as follows:

Class A Coupler Ultimate Capacity = 6.10*1.50
= 9.15 kN

GKN Capacity

120.0mm x 60.0mm x 4.0 RHS S355



GKN Section

h =	120	mm
b =	60	mm
L =	2400	mm
L_E =	2400	mm
E =	210000	N/mm^2
f_y=	355	N/mm^2
f_u=	510	N/mm^2
A=	1360	mm^2
I_x=	2490000	mm^4
I_y=	1310000	mm^4
$W_{el,x}$=	41500	mm^3
$W_{pl,x}$=	51900	mm^3
$W_{el,y}$=	28900	mm^3
$W_{pl,y}$=	31700	mm^3
r_y=	25	mm

GKN X Bending Moment

$M_{cr,x}$= $W_{p,l}.f_y/\gamma_{m0}$

$W_{pl,x}$=	51.90	cm^3
f_y=	355	N/mm^2
γ_{m0}=	1	

= 51.90*355/1000

= 18.42 kNm

GKN Y Bending Moment

$M_{cr,y}$= $W_{p,l}.f_y/\gamma_{m0}$

$W_{pl,y}$=	31.70	cm^3
f_y=	355	N/mm^2
γ_{m0}=	1	

= 31.70*355/1000

= 11.25 kNm

GKN Shear

$V_{pl,Rd}$= $A_v.f_y/sqrt(3)/\gamma_{m0}$

A_v= Ah/(b+h)

= 906.67 mm^2

f_y= 355 N/mm^2

γ_{m0}= 1.00

= (906.67*355)/sqrt(3)/1000

= 185.83 kN

GKN Compression Capacity

Effective Length = 2.40m

$N_{b,Rd}$ = $\chi A f_y / \gamma_{m1}$

χ = $1/ \phi+\sqrt{\phi^2-\lambda^{-2}}$

ϕ= $0.5(1+\alpha(\lambda^{-}-0.2) + \lambda^{-2}$

λ^{-} = $\sqrt{A f_y/N_{cr}}$

α = 0.21 Table 6.1

N_{cr}= π^2EI/L^2

E= 210000 N/mm^2

I= 1,310,000 mm^4

L= 2,400 mm

= PI()^2*210000*1310000/(2400^2)

= 471,376.42 N

λ^{-} = $\sqrt{A f_y/N_{cr}}$

A = 1,360 mm^2

f_y= 355 N/mm^2

λ^{-} = 1.01

ϕ= $0.5(1+\alpha(\lambda^{-}-0.2) + \lambda^{-2})$

α = 0.21

ϕ= 1.10

χ = $1/ \phi+\sqrt{\phi^2-\lambda^{-2}}$

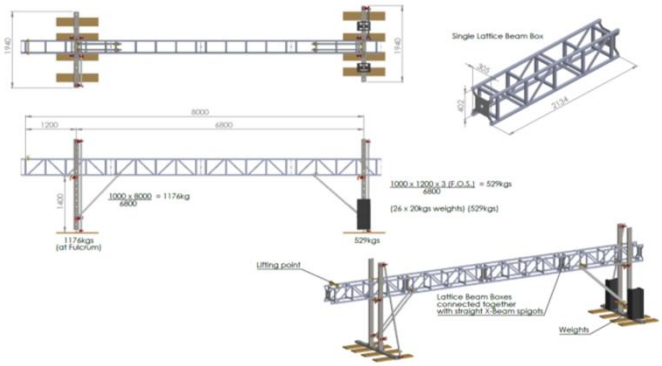
χ = 0.66

$N_{b,Rd}$ = $\chi A f_y / \gamma_{m1}$

= 0.66*1360*355/1000

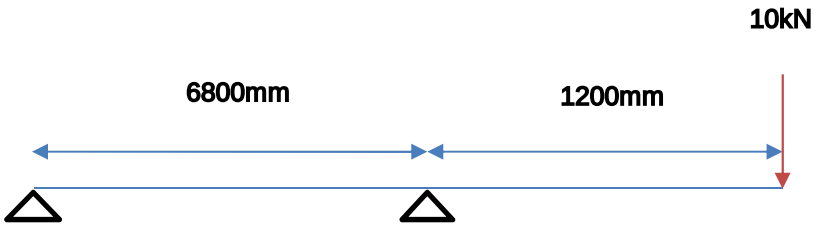
$N_{b,Rd}$ = 318.65 kN

Lattice Beam Loading



Beam Forces

Below are the unfactored forces applied to the 2No lattice beams from the winch:



Moment and Shear are calculated below:

M_x = P*a

P = 10.00 kN
a = 1.20 m

= 10.00*1.20
= 12.00 kNm

M_Y = 0.1*M_X

M_X = 12.00 kNm

= 0.10*12.00
= 1.20 kNm

V_1 = P*a/l

P = 10.00 kN
a = 1.20 m
l = 6.80 m

= 10.00*1.20/6.80
= 1.76 kN

V_2 = P

P = 10.00 kN

= 10.00 kN

Reaction of the GKN leg is calculated below.

$R_1 = V_1$

$V_1 = 1.76$ kN

$= 1.76$ kN

$R_2 = V_1+V_2$

$V_1 = 1.76$ kN

$V_2 = 10.00$ kN

$= 1.76+10.00$

$= 11.76$ kN

Below are the unfactored forces applied to the lattice beam from wind:

$M_Y = P_w*L^2/8$

$P_w = 0.09$ kN/m

$L = 6.80$ m

$= 0.09*6.80^2/8$

$= 0.52$ kNm (SLS)

The total horizontal load applied to the lattice beam is therefore:

$M_Y = 1.20+0.52$

$= 1.72$ kNm

Ultimate Beam Forces

The ultimate beam forces applied are below:

Lattice Beam:

$M_X = 30.00$ kNm (ULS - FOS = 2.5)

< 53.46 kNm ok

$M_Y = 4.30$ kNm (ULS - FOS = 2.5)

< 5.32 kNm ok (4No Booms)

$V = 25.00$ kN (ULS - FOS = 2.5)

< 52.14 kN ok

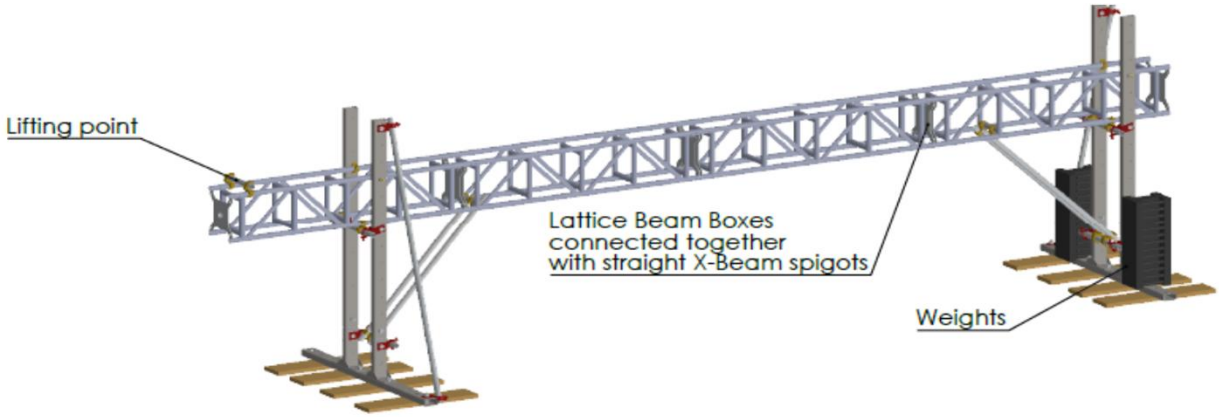
GKN Leg:

$N = 29.40$ kN (ULS - FOS = 2.5)

< 318.65 kN ok

Bracing & Connection Check

The head of the leg is braced by raking scaffold tubes which are connected by a bolted half coupler:



Bracing Scaffold Tube Loading

From the wind calculation the strom wind applies:

w_H= 0.09 kN/m (Wind Calculation)

Total Length = 1.40+1.20+6.80+1.40
= 10.80 m

Wind Force = 0.09*10.80
= 0.97 kN

10% Notional Load = 0.10*10.00
= 1.00 kN

Total Horizontal Force = 1.97 kN

For a raking tube at 72° the applied force is:

F= w_H/(cos(radians(Φ)))
= 1.97/(cos(radians(72)))
= 6.38 kN
Over 2No Braces = 3.19 kN

The axial capacity of a scaffold tube is as follows:

Allowable Axial Load = 8.70 kN (TG20 C.1 L = 2.50m)
> 3.19 kN ok

Bracing Scaffold Tube Coupler Check

The capacity of a Class A coupler is stated below:

Coupler SWL = 6.10 kN (TG20 T5.15)
> 3.19 kN ok

Bracing Coupler Bolt Check

The half coupler is connected to the Lattice Beam by an M12 Grade 8.8 bolt:

M12 Grade 8.8 Shear Capacity =	27.50	kN		
>	3.19	kN	ok	

Lattice Beam to GKN Leg Connection

The connection of the leg to the main boom is connected by 2No M12 bolts with Class A couplers & 2No Class A coupler GKN brackets. The reaction at the leg is calculated below:

Leg Reaction =	P/L*(L+a)			
			P =	10.00 kN
			L =	6.80 m
			a =	1.20 m
=	(10.00/6.80)*(6.80+1.20)			
=	11.76	kN		
FOS 2.50 =	29.41	kN		
M12 Grade 8.8 Shear Capacity =	27.50	kN		
2No =	55.00	kN		
>	29.41	kN	ok	
Class A Coupler Capacity =	9.15	kN		
4No =	36.60	kN		
>	29.41	kN	ok	

From tables for an M12 Grade 8.8 bolt, bearing on a 5mm S355 box wall is:

Bearing Capacity =	30.30	kN		
2No =	60.60	kN		
>	29.41	kN	ok	

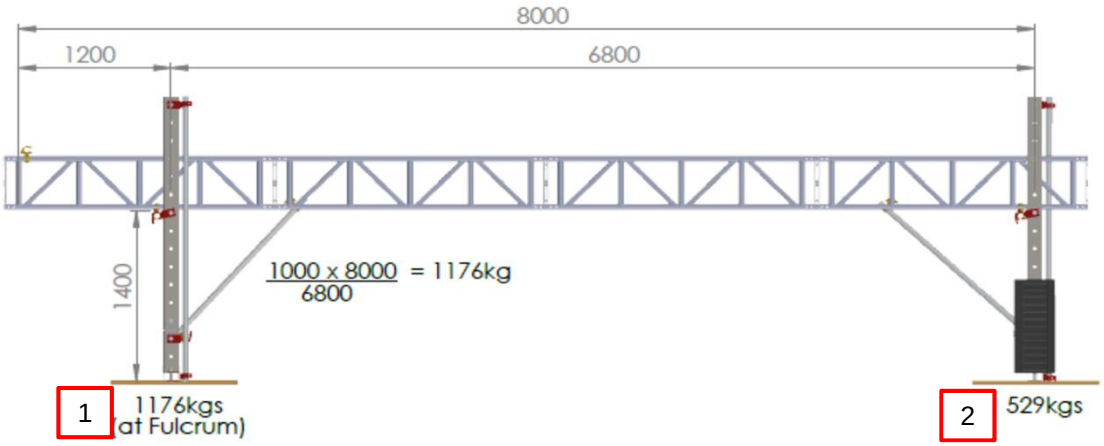
Local Lifting Tube

Support Reaction =	10.00	kN		

The applied moment and shear to the lifting tube is calculated below:

M =	PL/4			
			P =	10.00 kN
			L =	0.31 m
=	10.00*0.31/4			
=	0.78	kNm		
2.50 FOS =	1.94	kNm		
<	2.19	kNm	ok	
V =	P/2			
			P =	10.00 kN
=	10.00/2			
=	5.00	kN		
2.50 FOS =	12.50	kN		
<	48.18	kN	ok	

Unfactored Reactions



Reactions below are unfactored and are in kN:

Support	X3
1	11.76
2	-1.76

Kentledge Required

A FOS of 3 is required on kentledge:

Kentledge Required =	3*1.76		
=	5.28	kN	
=	528.00	kg	
Kentledge Provided =	529.00	kg	
>	528.00	kg	ok

Downforce Applied to Roof

The unfactored downforce applied to the roof from the imposed load is stated below:

Unfactored Load on Roof =	11.76	kN
=	1,176.47	kg

Sliding Check

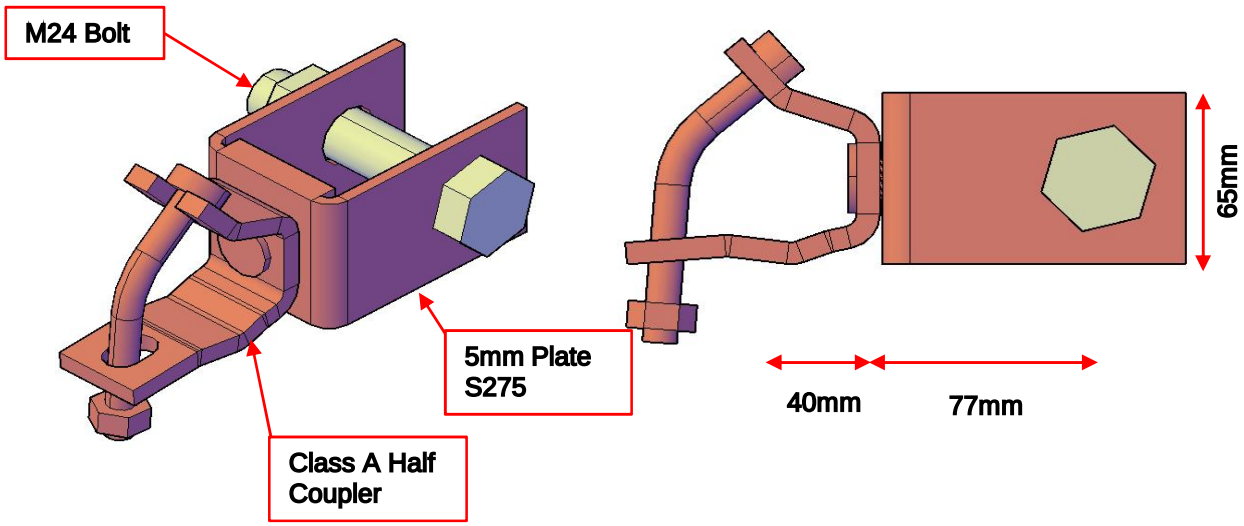
Sliding of the rig is assessed for storm wind loading:

Storm Wind Force =	0.97	kN	(Bracing & Connections)
Sliding Coefficient =	0.40		

Kentledge required to resist sliding is therefore:

Kentledge Required =	0.97/0.40	
=	2.43	kN
=	242.50	kg
<	529.00	kg

Class A GKN Bracket



The bracket above must resist the force specified below:

Lattice Box Beam Reaction =	11.76	kN	
FOS 2.5 =	29.41	kN	
Over 4No Connections =	7.35	kN	
Class A Coupler Ultimate Capacity =	9.15	kN	
>	7.35	kN	ok

The moment and shear force applied to the bracket plate is calculated below:

M = P*a

P = 7.35 kN

a = 0.04 m

= 7.35*0.04

= 0.29 kNm

V = P

P = 7.35 kN

= 7.35 kN

Moment and shear capacity of the 5mm plate is below:

W_{pl} = $bd^2/4$

b = 0.50 cm

d = 6.50 cm

= 0.5*6.5^2/4

= 5.28 cm^3

A = b*d

b = 5.00 mm

d = 65.00 mm

= 5.00*65.00

= 325.00 mm^2

Plate Bending Moment

$M_{cr,x}$= $W_{p,l}.f_y/\gamma_{m0}$

$W_{pl,x}$= 5.28 cm^3

f_y= 275 N/mm^2

γ_{m0}= 1

= 5.28*275/1000

= 1.45 kNm

> 0.29 kNm ok

Plate Shear

$V_{pl,Rd}$= $A_v.f_y$/sqrt(3)/γ_{m0}

A_v= 0.80*A

= 260.00 mm^2

f_y= 275 N/mm^2

γ_{m0}= 1.00

= (260.00*275)/sqrt(3)/1000

= 41.28 kN

> 7.35 kN ok

Bolt Reaction

R = M/LA

M = 0.29 kNm

LA = 0.077 m

= 0.29/0.077

= 3.77 kN

Conservatively assume that the connection force is added to bolt reactions:

Bolt Reaction = 3.77+7.35

= 11.12 kN

M24 Grade 8.8 Shear Capacity = 136.00 kN

> 11.12 kN ok

Summary

All members have passed design checks for the specified loading.

Scaffold components must be as per TG20:13.

GKN steelwork grade must be S355.

Raking scaffold bracing is required to the top of the GKN leg.

GKN leg to beam connection must be made with a 2No M12 Grade 8.8 bolts with couplers.

Lattice beams are connected with spigots.

This design does not include a check of the existing structure.

529kg of kentledge is required at the rear of the rig.

Maximum unfactored load applied to the roof is 11.76kN.