APOLLO SCAFFOLD SERVICES LTD
1.3M X-BEAM SPIGOT CONNECTION
DESIGN CHECK CALCULATIONS

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CALCULATION SHEET	Project :	Apollo - 1.3m X- Beam Spigot Connection		
	Element :	Brief		
	Job Number :	V0095	By : mrb	Date: Feb 16
	Document No :	002	Checked :mmr	Date: Feb 16

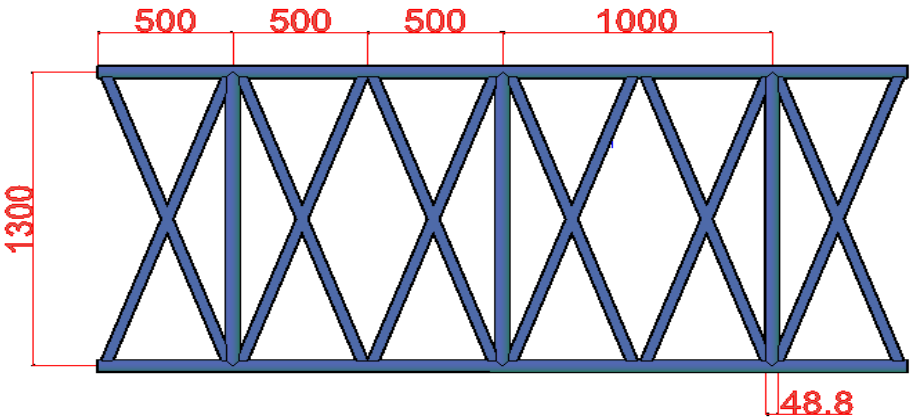
ALAN WHITE DESIGN

Brief

To check the capacity of the spigot for connecting booms of the Apollo aluminium 1.3m X-beams.

Layout

Layout of 1.3m X-beam as below:



1.30m X-beam

Design

Design of Steel Structures	EN 1993-1-1
Design of Aluminium Structures	EN-1999-1-1

The following AWD documents are referenced:

Apollo 1.3m X-beam calc	V0095-001

Design assumptions

Steelwork yield strength for CHS members is 355N/mm^2

Aluminium yield strength for Solid bar is 255N/mm^2

All bolts M12 Grade 8.8
Note the steel design factor of safety is 1.5 for live loads

Analysis

From the calculations for the X-beam V0095-001:

Maximum Boom Capacities:

Moment	1.04	kNm	ULS
Shear	32.91	kNm	ULS
Tension	90.13	kN	ULS
Compression	103.22	kN	ULS

Design capacities

From above the spigots require to have the following capacities

Moment	1.04	kNm	ULS
Shear	32.91	kNm	ULS
Tension	90.13	kN	ULS
Compression	103.22	kN	ULS

CALCULATION SHEET	Project :	Apollo - 1.3m X- Beam Spigot Connection		
	Element :	Steel Spigot Capacity		
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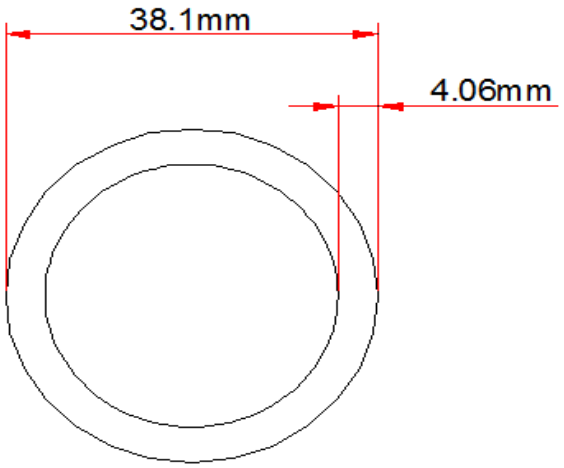
ALAN WHITE DESIGN

Steel Spigot Section

38.1 x 4.06 CHS S355



Steel Spigot Section

A=	434	mm^2
I=	63781	mm^4
$W_{el,x}$=	3348	mm^3
$W_{pl,x}$=	4520	mm^3
r_y=	12	mm

Applied Loads

Moment	$M_{Rd,x}$=	1.04	kNm
Shear	V_{Rd}=	32.91	kN
Tension	$N_{u,Rd}$=	90.13	kN
Compression	$N_{b,Rd}$=	103.22	kN

Steel Spigot Bending Moment Capacity

$M_{cr,x}$= $W_{p,l}.f_y/\gamma_{m0}$ $W_{pl,x}$= 4.52 cm^3

f_y= 355 N/mm^2

γ_{m0}= 1.00

= 4.52*355/1000

= 1.60 kNm

> 1.04 kNm ok

Steel Spigot Shear Capacity

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

A_v= 0.6A

A_v= 260 mm^2

f_y= 355 N/mm^2

γ_{m0}= 1.00

= 260*355/sqrt(3)/1000

= 53.29 kN

> 32.91 kN ok

Steel Spigot Tension Capacity

plastic resistance

N_{plr}= $A.f_y/\gamma_{m0}$

A_e= $A-A_{(2\ bolt\ holes)}$

A_e= 434-2*13*4.06

A_e= 328.44 mm^2

f_y= 355 N/mm^2

γ_{m0}= 1.00

= 328.44*355/1000

= 116.60 kN

ultimate resistance

N_{ur}= $0.9A.f_u/\gamma_{m2}$ 0.9A= 296 mm^2

f_u= 510 N/mm^2

γ_{m2}= 1.25

= 296*510/1250

= 120.77 kN

Lesser Value= 116.60 kN

> 90.13 kN ok

.

Steel Spigot Compression Capacity

$N_{b,Rd}$= X A f_y/γ_{m2}

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

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= 63781 mm^4

L= 220 mm

= pi()^2*210000*63781/(220^2)

= 2,731,272.31 N

λ^{-}= $\sqrt{Af_y/N_{cr}}$

A= 434 mm^2

f_y= 355 N/mm^2

= 0.24

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

α= 0.21 Table 6.1

= 0.53

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

= 0.99

$N_{b,Rd}$= X A f_y/γ_{m0}

$N_{b,Rd}$= 152.85 kN

> 103.22 kN ok

Bearing in spigot

Bolts are M12 grade 8.8

$F_{b,Rd}= k_1 \alpha_b f_u d t / \gamma_{M2}$

d_o=	13	mm	
e_1=	40	mm	
e_2=	40	mm	
k_1=	6.92		>2.5
therefore k_1=	2.5		
t=	4.06	mm	
d=	12	mm	
f_u=	510	N/mm^2	
f_{ub}=	800	N/mm^2	
γ_{M2}=	1.25		
α_b=	1.03		>1
Therefore, α_b=	1.00		

$F_{b,Rd}$= (2.5*1.00*510*12*4.06)/1250
= 49.69 kN

Load transferred via 2No Bolts with 2No holes leading to 4No Bearing surfaces

Total Bearing capacity= 4*49.69
$F_{b,Rd}$= 198.76 kN
> 103.22 kN **OK**

Bearing in boom

Bolts are M12 grade 8.8

$F_{b,Rd}= k_1 \alpha_b f_u d t / \gamma_{M2}$

d_o=	13	mm	
e_1=	40	mm	
e_2=	40	mm	
k_1=	6.92		>2.5
therefore k_1=	2.5		
t=	4.4	mm	
d=	12	mm	
f_u=	295	N/mm^2	
f_{ub}=	800	N/mm^2	
γ_{M2}=	1.25		
α_b=	1.03		>1
Therefore, α_b=	1.00		

$F_{b,Rd}$= (2.5*1*295*12*4.4)/1250
= 31.15 kN

Load transferred via 2No Bolts with 2No holes leading to 4No Bearing surfaces

Total Bearing capacity= 4*31.15
$F_{b,Rd}$= 124.60 kN
> 103.22 kN **OK**

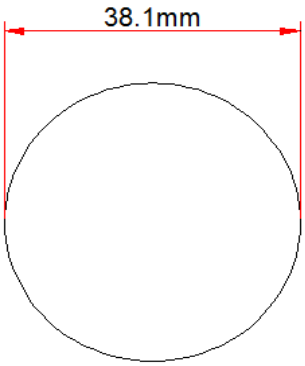
Shear in Connection Pins

Bolts are M12 grade 8.8

Shear Capacity =	55.00	kN	(Double Shear)
No of Bolts =	2.00	No	
Total Shear Capacity =	110.00	kN	
>	103.22	kN	**OK**

Aluminium Spigot Section

38.1 mm CHS The section of the aluminium spigot is a solid bar with 2 holes through each end to match the holes in the end of the booms.



Aluminium Spigot Section

A=	1140	mm^2
I=	103435	mm^4
$W_{el,x}$=	5430	mm^3
$W_{pl,x}$=	9230	mm^3
r_y=	10	mm

Applied Loads

Moment	$M_{Rd,x}$=	1.04	kNm
Shear	V_{Rd}=	32.91	kN
Tension	$N_{u,Rd}$=	90.13	kN
Compression	$N_{b,Rd}$=	103.22	kN

Aluminium Spigot Moment Capacity (6.2.5.1)

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

α =	W_{pl}/W_{el}	(Table 6.4)	
=	1.70		
W_{el} =	5.43	cm^3	
f_o =	255	N/mm^2	
γ_{M1} =	1.10	(6.1.3)	

= 1.70*5.43*255/1100

$M_{c,Rd}$ = 2.14 kNm

> 1.04 kNm ok

Aluminium Spigot Shear Capacity (6.2.6)

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

A_v=	$0.8A_e$	
=	912	mm^2
γ_{M1}=	1.10	
f_o =	255	N/mm^2

= 912*255/(SQRT(3)*1100)

V_{Rd} = 122.06 kN

> 32.91 kN

Aluminium Spigot Axial Tension Capacity (6.2.3)

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

$f_o =$ 255 N/mm^2

$A_g =$ 1140 mm^2

$\gamma_{M1} =$ 1.1

$= 1140*255/1100$

$=$ 264.27 kN

Local failure

$N_{u,Rd} = 0.9 A_{net} f_u / \gamma_{M2}$

$f_u =$ 295 N/mm^2

$A_{net} =$ $A-A_{(1\ Bolt\ Hole)}$

$=$ 644.7 mm^2

$\gamma_{M1} =$ 1.25

$= 0.9*644.7*295/1250$

$=$ 136.79 kN

Lesser Value= 136.79 kN

> 90.13 kN

Aluminium Spigot Compression Capacity

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

$k = \omega_x$

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

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

$= 0.65$

$k = 0.65$

$N_{cr} = \pi^2 EI / k^2 L^2$

$E =$ 70,000 N/mm^2

$I =$ 103,435 mm^4

$k =$ 0.50

$L =$ 220 mm

$N_{cr} = ((PI()^2)*70000*103435)/((0.5^2)*(220^2))$

$=$ 5,905,816.30 N

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

$A =$ 1,140 mm^2

$=$ 0.22

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

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

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

$\lambda_o =$ 0.10 Table 6.6

$\Phi =$ 0.54

$X =$ 0.94

$N_{b,Rd} = 0.65*0.94*1140*255/1100$

$=$ 161.47 kN

> 103.22 kN

Bearing in spigot

Bolts are M12 grade 8.8

$F_{b,Rd}= k_1 \alpha_b f_u d t/\gamma_{M2}$

d_o=	13	mm	
e_1=	40	mm	
e_2=	40	mm	
k_1=	6.92	>2.5	
therefore k_1=	2.5		
t=	38.1	mm	
d=	12	mm	
f_u=	295	N/mm^2	
f_{ub}=	800	N/mm^2	
γ_{M2}=	1.25		
α_b=	1.03	>1	
Therefore, α_b=	1.00		

$F_{b,Rd}$= (2.5*1.00*295*12*38.1)/1250

= 269.75 kN

> 103.22 kN ok

Bearing in boom

Bolts are M12 grade 8.8

$F_{b,Rd}= k_1 \alpha_b f_u d t/\gamma_{M2}$

d_o=	13	mm	
e_1=	40	mm	
e_2=	40	mm	
k_1=	6.92	>2.5	
therefore k_1=	2.5		
t=	4.4	mm	
d=	12	mm	
f_u=	295	N/mm^2	
f_{ub}=	800	N/mm^2	
γ_{M2}=	1.25		
α_b=	1.03	>1	
Therefore, α_b=	1.00		

$F_{b,Rd}$= (2.5*1.00*295*12*4.4)/1250

= 31.15 kN

Load transferred via 2No Bolts with 2No holes leading to 4No Bearing surfaces

Total Bearing capacity= 4*31.15

$F_{b,Rd}$= 124.60 kN

> 103.22 kN ok

Shear in Connection Pins

Bolts are M12 grade 8.8

Shear Capacity =	55.00	kN	(Double Shear)
No of Bolts =	2.00	No	
Total Shear Capacity =	110.00	kN	
>	103.22	kN	**OK**

Results

	Action	Formula	Ultimate	Calculated	Factor
Steel Spigot Capacity					
	Moment	$M_{Rd,x}$	1.60	1.04	0.65
	Shear	V_{Rd}	53.29	32.91	0.62
	Tension	$N_{u,Rd}$	116.60	90.13	0.78
	Compression	$N_{b,Rd}$	152.85	103.22	0.68
	Bearing - Spigot	$F_{b,Rd}$	198.76	103.22	0.52
	Bearing - Boom	$F_{b,Rd}$	124.60	103.22	0.83
Alu Spigot Capacity					
	Moment	$M_{Rd,x}$	2.14	1.04	0.49
	Shear	V_{Rd}	122.06	32.91	0.27
	Tension	$N_{u,Rd}$	136.79	90.13	0.66
	Compression	$N_{b,Rd}$	161.47	103.22	0.64
	Bearing - Spigot	$F_{b,Rd}$	269.75	103.22	0.39
	Bearing - Boom	$F_{b,Rd}$	124.60	103.22	0.83

Summary

The required capacity of the 1.3m X-beam was extracted from AWD design calculation V0095-001. These capacities were compared to the capacities of spigots made from two different types of material.

The spigots that were checked were:

Steel	38.1mm diameter 4.06mm seamless tube to Grade S355.
Aluminium	38.1 diameter solid bar made from 6082T6 aluminium alloy

The calculations showed that both of these spigots have the required capacities and are suitable for use for the 1.3m X-beam boom connection.