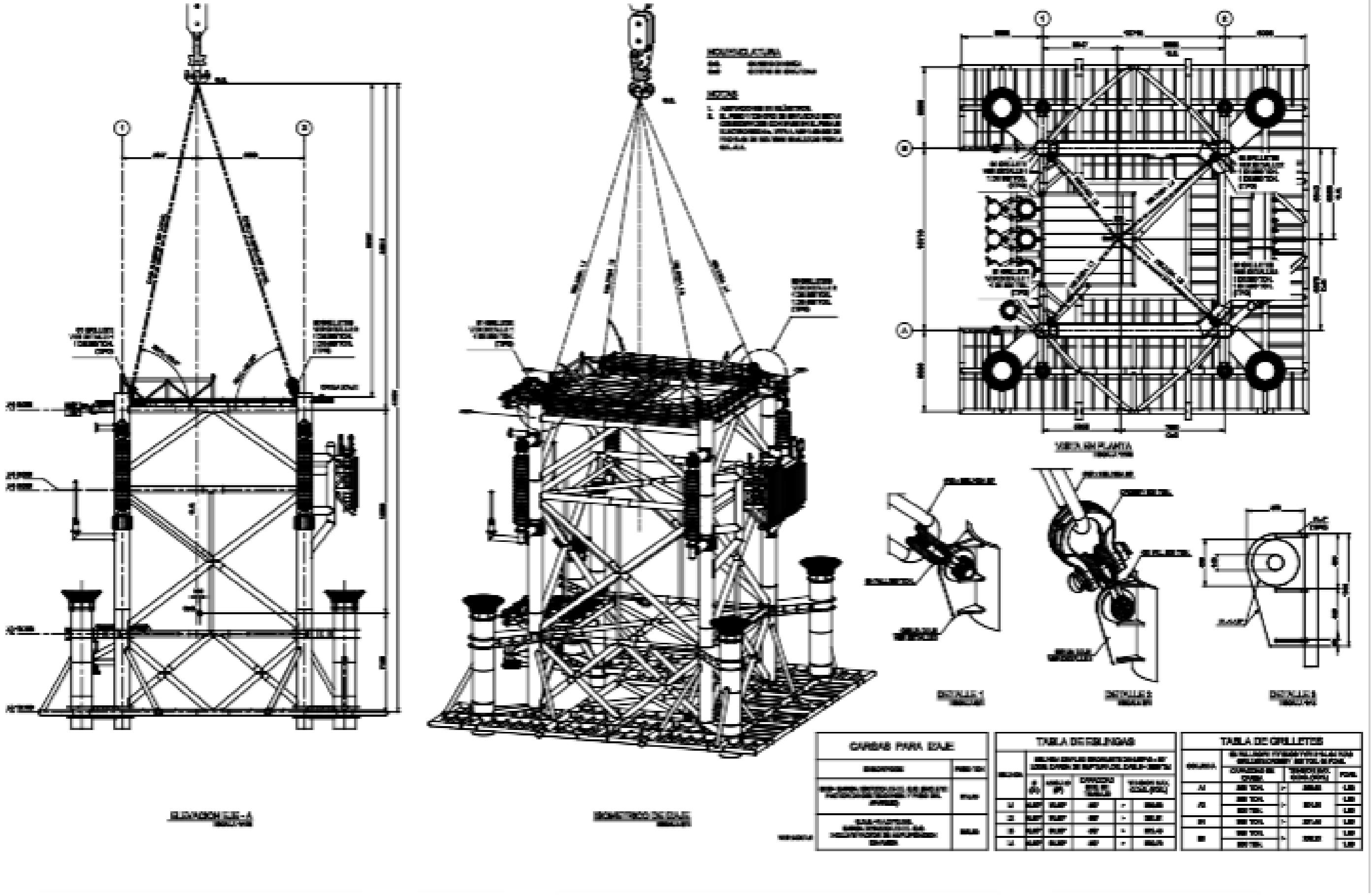
# Structural Engineering Course
# Basic Level

MOSES
INSTITUTE

# Sylabus Basic Level (12x 2 hours meeting)

1. Material & Element
2. Engineering Mechanic & Structural Behaviour
3. Introduction to Design Code Criteria
4. Environment load 1
5. Environment load 2
6. Environment load 3
7. Environment load 4
8. Preservice – Weighing
9. Preservice - Lifting
10. Preservice - Land Transport
11. Preservice – Sea Transport
12. Final Assignment

# Lifting Arrangement




[Ref: Hok-a substructure lifting arrangement (13.31 MB) | Bibliocad]

# Sling Forces

MEMBER FORCES AND MOMENTS REPORT

| MEMBER NUMBER | MEMBER END | GROUP ID | LOAD COND | FORCE(X) (kN) | FORCE(Y) (kN) | FORCE(Z) (kN) |
|---|---|---|---|---|---|---|
| P501-PDY1 | P501 | PDY | 4000 | 9828.1377 | 1334.2141 | -0.6788 |
| | | | 4100 | 9726.8271 | 1331.2980 | -1.6778 |
| | | | 4200 | 7808.6665 | 1075.7202 | -1.8225 |
| | | | 4300 | 9929.4365 | 1337.1292 | 0.3201 |
| | | | 4400 | 11847.5967 | 1592.7068 | 0.4649 |
| | PDY1 | | 4000 | 9828.1377 | 1334.2141 | -0.6788 |
| | | | 4100 | 9726.8271 | 1331.2980 | -1.6778 |
| | | | 4200 | 7808.6665 | 1075.7202 | -1.8225 |
| | | | 4300 | 9929.4365 | 1337.1292 | 0.3201 |
| | | | 4400 | 11847.5967 | 1592.7068 | 0.4649 |

# Load Factors

| Combination Factor | Factor | | | | | Total Factor |
|---|---|---|---|---|---|---|
| | SLF | TEF | YEF | DAF | CF | |
| a1 | 1.1 | 1.05 | 1.0 | 1.0 | 1.0 | 1.155 |
| a2 | 1.1 | 1.05 | 1.0 | 1.05 | 1.0 | 1.212 |
| a3 | 1.1 | 1.05 | 1.0 | 1.05 | 1.15 | 1.394 |
| a4 | 1.1 | 1.05 | 1.0 | 1.05 | 1.30 | 1.576 |

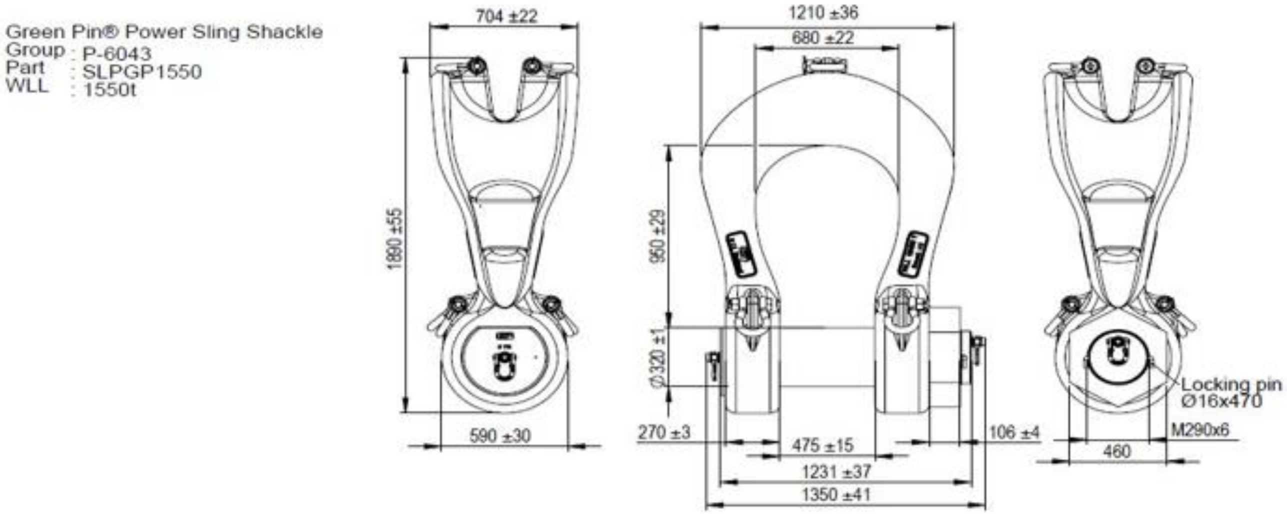
# Lifting Gears Calculation

| | | | | |
|---|---|---|---|---|
| Factored sling load | Fsf | = | 11000.0 | kN, From SACS lifting case output. |
| Combination factor for padeyes calc | a4 | = | 1.576 | |
| Basic sling load = Fsf/a4 | Fs | = | 711.5 | MT (Metric Ton) |
| Basic load for padeye, Fpb: | Fpb | = | 711.5 | MT |
| Weight contingency | γwc | = | 1.00 | (included in SACS model) |
| COG shift | γcog | = | 1.00 | |
| DAF | γdaf | = | 1.05 | |
| SKL | γskl | = | 1.10 | |
| Tilt Factor | γt | = | 1.05 | |
| Yaw Factor | γw | = | 1.00 | |
| Sling design load, Fsd=Fs*γwc*γcog*γdaf*γt*γw*γskl | Fsd | = | 862.9 | MT 1902.6 Kips DNVGL-ST-N001 (2016) sec.16.3.4.1 |

**Dimension of Shackle**

| | | | | | | |
|---|---|---|---|---|---|---|
| Provided Shackle: | | | Green Pin P-6043, SLPGP1550 | with the following data : | | |
| Shackle Safe Working Load (SWL) | SSWL | = | 1560.0 | MT | | |
| Shackle Min Breaking Load MBL | SMBL | = | 7800.0 | MT | | |
| Proof load test result | PLT | = | 1560.0 | MT | (presumed, not available yet) | |
| Pin Diameter | $d_p$ | = | 320.0 | mm | | |
| Jaw Width | Bsh | = | 460.0 | mm | | |
| Inside Length | Hsh | = | 950.0 | mm | | |
| Check Fsd<SSWL*DAF | 862.9 MT | < | 1638.0 | MT | DNVGL-ST-N001 (2016) sec.16.5.2.5 | **...Accepted** |
| Unity Check | UC | = | **0.527** | | | |
| Check Fsd<SMBL/3 | 862.9 MT | < | 2600.0 | MT | DNVGL-ST-N001 (2016) sec.16.5.2.5 | **...Accepted** |
| Unity Check | UC | = | **0.332** | | | |
| Check Fsd<PLT | 862.9 MT | < | 1560.0 | MT | DNVGL-ST-N001 (2016) sec.16.5.2.5 | **...Accepted** |
| Unity Check | UC | = | **0.553** | | | |

# Lifting Gears Calculation




**Dimension of Sling**

| | | | | |
|---|---|---|---|---|
| Nominal safety factor for sling, γsf=max(2.3,γf*γc*γr*γw*γm) | | | | DNVGL-ST-N001 (2016) sec.16.4.3 |
| | γsf | = | 3.26 | |
| Where | | | | |
| Lifting factor | γf | = | 1.30 | |
| Consequence factor | γc | = | 1.30 | |
| Reduction factor, γr=max(γs,γb) | γr | = | 1.30 | |
| Termination factor | γs | = | 1.30 | |
| Bending factor, fb=1/(1-0.5/(Dsh/dsl)^0.5) | γb | = | 1.00 | (Ignored as the bending is at the eye sling) |
| Material factor | γm | = | 1.35 | |
| Wear factor | γw | = | 1.10 | |
| Required Nominal MBL of sling, MBLr > γsf*Fsd | MBLr | = | 2815.1 MT | DNVGL-ST-N001 (2016) sec.16.4.2.0 |
| | | = | 27616.2 kN | |

# Lifting Gears Calculation

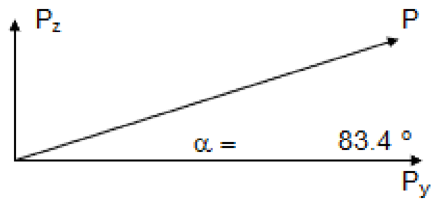
| | | | | | |
|---|---|---|---|---|---|
| Provide sling rope | | = | IWRC 6x36 grade 1770 | | |
| Choose sling rope above MBL | | = | 7750.0 MT | (assumed) | |
| Diameter of Sling | dsl | = | 162.0 mm | | |
| Unity Check MBLr/MBL ≤ 1 | UC | = | **0.363** | | **...Accepted** |

**D. Criteria for Padeye Sizing**

| | | | | |
|---|---|---|---|---|
| Diameter of pin hole | $d_h$ = Max(dp+2mm,min(1.03*dp,dp+6)) | = | 326.00 mm | DNVGL-ST-N001 (2016) sec.16.9.5.2 |
| Radius of pin hole | $r_h$ | = | 163.00 mm | Pin Hole Radius for the padeye |

**E. Lift Point Load**

| | | | |
|---|---|---|---|
| Lift Point Design Load | Fp=Fpb*γwc*γcog*γdaf*γt*γw*γskl*γc | = | 1121.7 MT |
| | | = | |
| Load angle | α | = | **83.4** degree |




| | | | |
|---|---|---|---|
| P | = | | 1121.7 MT |
| $P_z$ | = | P sin α = | 1114.3 MT |
| $P_y$ | = | P cos α = | 128.9 MT |

# Lifting Gears Calculation

**F. Padeye Code Check**

Try the following plate thickness :

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| - Thickness main plate | ($t_m$) | = | 100 | mm | | | |
| - Max thickness cheek plate 1 | ($t_{c1}$) | = | 100 | mm | | | |
| - Max thickness cheek plate 2 | ($t_{c1}$) | = | 0 | mm | | | |
| - Total Provide thickness cheek plate | | = | 100.0 | mm | | | |
| - Total thickness of padeye (before spacer) | tp | = | $t_m+2*t_{c1}+2*t_{c2}$ | | | | |
| | | = | 300.0 | mm | Jaw width, Bsh= | 460.0 | |
| - Actual gap distance between padeye thickness and jaw width, g1=Bsh-tp | | | | | | | |
| | g1 | = | 160.0 | mm | | | |
| - Actual gap in each side, g2=g1/2 | g2 | = | 80.00 | mm | | | |
| - Design gap in each side: | g3 | = | 30.00 | mm | | | |
| - Req. thk. of spacer plate, tsp=g2-g3 | tsp | = | 50.00 | mm (each side) | | | |
| - Provided thk. of spacer plate, tsp | tsp | = | 50.00 | mm | | | **...Accepted** |
| - Gap distance Inside Length | | = | H+dp/2-rm-ds > 1.3*d | | | | |
| | | = | 308.00 | mm | > | 210.6 mm | **...Accepted** |
| - Stiffener plate thickness | ts | = | 38 | mm | | | |
| - Total thickness of padeye (with spacer) | tp' | = | $t_m+2*(Tsp+t_{c1},t_{c2})$ | | | | |
| | | = | 400.0 | mm | > Jaw width, Bsh= | 460.0 | **...Accepted** |
| - Main plate radius | $r_m$ | = | max of (1.25 x Diameter pin hole or Diameter pinhole/2 + 3") | | | | |
| | | = | 640 | mm | | | |
| - Cheek plate radius, rc=rm-tc | $r_c$ | = | main plate radius - thickness cheek plate | | | | |
| | | = | 540 | mm | | | |
| - $f_{yield}$ main plate | $f_{ym}$ | = | 355 | MPa | | | |
| - $f_{yield}$ cheek plate | $f_{yc}$ | = | 355 | MPa | | | |

# Lifting Gears Calculation

**Geometric check of Padeye (as per DNVGL ST N001 Sec. P.2.4.2)**

Outside radius of the padeye main plate shall be no less than the diameter of the pin hole

$r_m \geq$ p+6))

640.0 mm ≥ 326.0 mm ...**Accepted**

The pad eye thickness at the hole shall not be less than 75% the inside width of the shackle

tp' ≥ 75%* Bsh

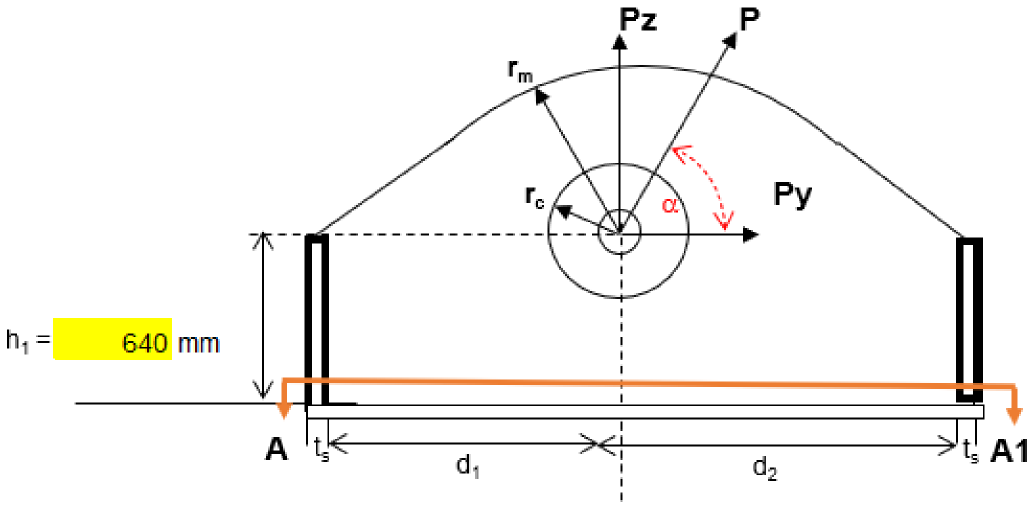
400.0 mm ≥ 345.0 mm ...**Accepted**

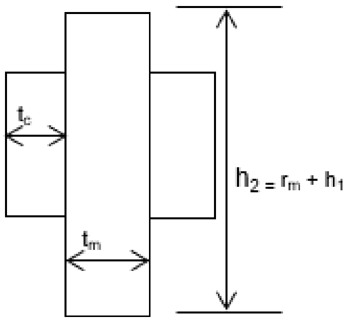
Shackle pin max. diameter including tolerance should be considered in order to ensure that the pin will enter the hole

ım,min(1.03 ≥ dp

356.0 mm ≥ 320.0 mm ...**Accepted**

**Sketch of Padeye**




tm= 100.0 mm

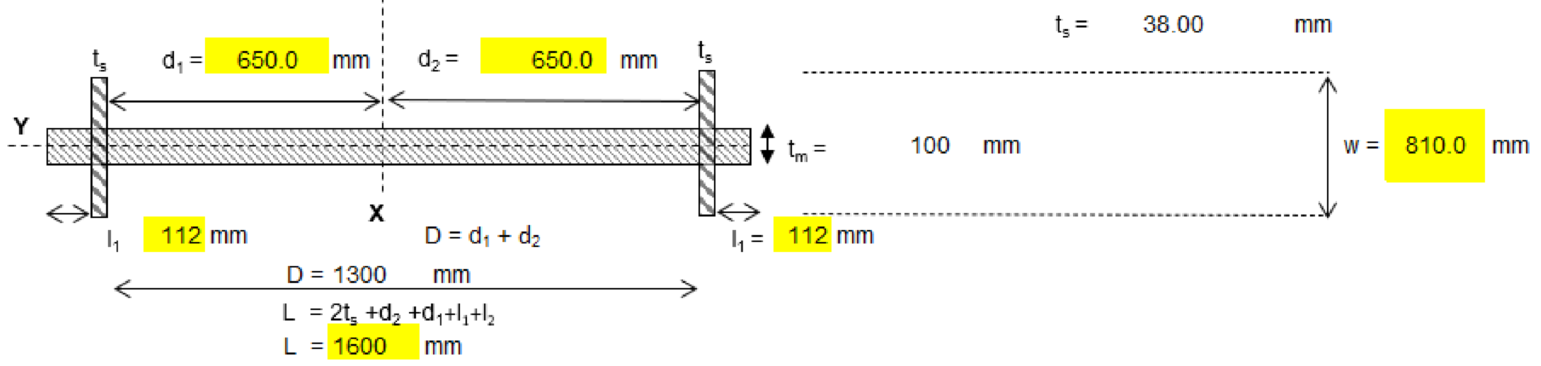
tc= 100.0 mm

h2= 1280.0 mm

# Lifting Gears Calculation

**section A-A1 :**

*(Assumed as Beam Section)*




**F.1 Pin Bearing Stress**

<u>Check Bearing Capacity</u>

| | | | | | | |
|---|---|---|---|---|---|---|
| Allowable Bearing Stress | | = | 0.9 x $f_{yield}$ | | | |
| | | = | 319.5 | MPa | | |
| Bearing Capacity : | | = | 0.9 x $f_{yield}$ x A | | | |
| | A | = | $d_p$ * t/sqrt(2) | | | |
| | | = | 67882.3 | $mm^2$ | | |
| Bearing capacity | | = | 0.9 x $f_{yield}$ x A | | | |
| | | = | 2210.8 | MT | | |
| Bearing Load | Fb | = | 1121.7 | MT | < Bearing Capacity | |
| Unity Check | | = | **0.510** | | < 1 | **...Accepted** |
| Bearing stress due to radial pressure | fb=Fb/(t*dp) | = | 114.6 | MPa | < 0.9*fy | |
| Unity Check | | = | **0.360** | | < 1 | **...Accepted** |

<u>Max stress due to pressure between elastic bodies</u>

| | | | | | | |
|---|---|---|---|---|---|---|
| Max stress | $f_{he}$ | = | 0.591 x sqrt F*E/Tt*KB | | ≤ 2.5 Fy | |
| | | = | 383.9 | MPa | < 888 MPa | |
| Unity Check | | = | **0.430** | | < 1 | **...Accepted** |

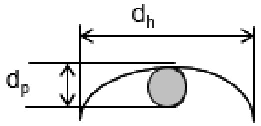
# Lifting Gears Calculation

Where,

| | | | | |
|---|---|---|---|---|
| Bearing Load | Fp | = | 11004013.3 | N |
| Bearing load per unit length of contact surface, p =Fp/tp | | | | |
| | p | = | 36680.0 | N/mm |
| Young's Modulus | E | = | 200,000.0 | MPa |

Hertz pressure :

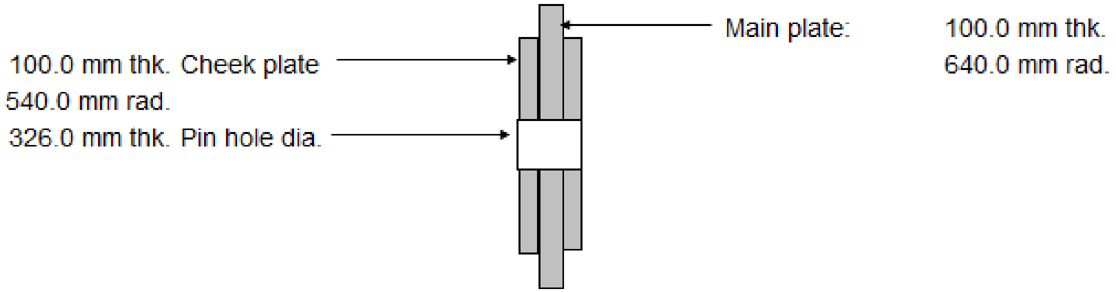
For 1560MT shackle Green Pin P-6043, SLPGP1550




| | | | | |
|---|---|---|---|---|
| Pin hole dia. | $d_h$ | = | 326.0 | mm |
| Pin dia. | $d_p$ | = | 320.0 | mm |
| | Kd | = | $(d_h \times d_p)/(d_h - d_p)$ | |
| | | = | 17386.7 | |

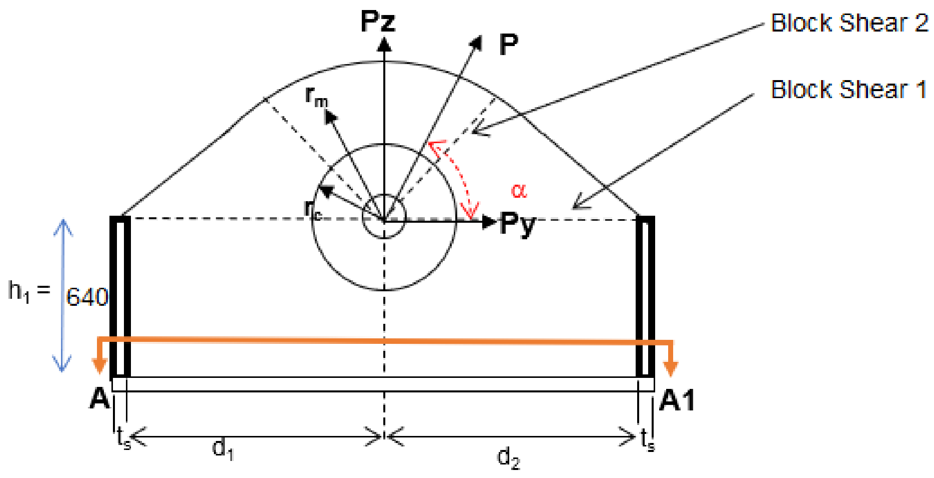
**F.2 Pin Pull-Out Shear**

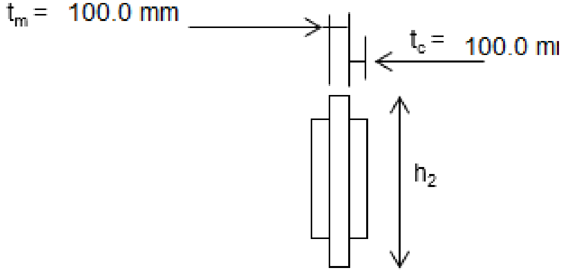
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Allowable Shear Stress | | = | 0.4 x Fy | | | | | |
| Shear force, Py | Py | = | 1121.7 | MT | | | | |
| | | = | 11004013.3 | N | | | | |
| Effective shear section area | Ae | = | (2 x (rm-dh/2) x tm) + (4 x (rc-dh/2) x tc) | | | | | |
| | | = | 246200.0 | mm2 | | | | |
| Shear Stress, fs=Py/Ae | fs | = | 44.7 | MPa | < | 0.4*Fy = | 142 MPa | |
| Unity Check | | = | **0.310** | | < 1 | | | **...Accepted** |



# Lifting Gears Calculation

### F.3 Tension Failure




| | | | | | | |
|---|---|---|---|---|---|---|
| Refer to AISC D1 - Block Shear 1 | | | | | | |
| Allowable Tensile Stress without pin hole | | = | 0.60 x Fy | | | |
| Maximum Tension | Ft=Pz | = | 1114.3 MT | | | |
| | | = | 10931086.8 N | | | |
| Effective tension section area | Ae | = | Block Shear 1 length x tm x 0.60 Fy | | | |
| | | = | (D-dh) x tm | | | |
| | | = | 974 x 100 | | | |
| | | = | 97400.0 mm2 | | | |
| Tensile Stress, ft=Ft/Ae | ft | = | 112.2 MPa | < 0.60 x Fy = | 213 MPa | |
| Unity Check | | = | **0.527** | < 1 | | **...Accepted** |
| | | | | | | |
| Refer to AISC D1 - Block Shear 2 | | | | | | |
| Allowable Tensile Stress without pin hole | | = | 0.60 x Fy | | | |
| | | = | 213 MPa | | | |
| Tensile Capacity | | = | Block Shear 2 length x $t_m$ x 0.60 Fy | | | |
| Effective tension section area | Ae | = | 2*(rm-dh/2) x tm | | | |

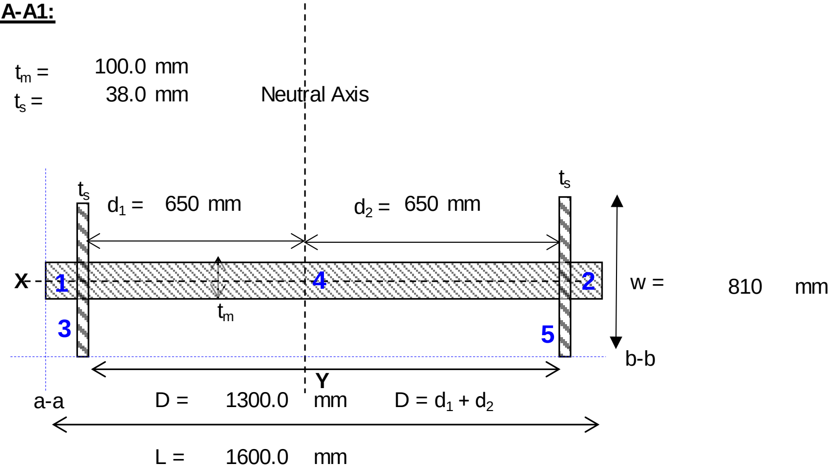
# Lifting Gears Calculation

| | | | | | |
|---|---|---|---|---|---|
| | | = | 954 x 100 | | |
| | | = | 95400.0 | mm2 | |
| Tensile Stress, ft=Ft/Ae | ft | = | 114.6 | MPa | < 0.60 x Fy = 213 MPa |
| Unity Check | | = | **0.538** | | < 1 **...Accepted** |

**F.4 Combined Stress**

| | | | | |
|---|---|---|---|---|
| Lift Point Design Load | P | = | 1121.7 | MT |
| | $P_z$ | = | P sin α | |
| | | = | 1114.3 | MT |
| | $P_y$ | = | P cos α | |
| | | = | 128.9 | MT |

**section A-A1:**




| No. | b | h | Area | Ordinat to a-b | | A*X' | A*Y' | Centre of Gravity | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | x' | y' | | | $X_{cog}$ | $Y_{cog}$ |
| | mm | mm | (mm2) | mm | mm | mm3 | mm3 | mm | mm |
| 1 | 112.0 | 100.0 | 11200 | 56.0 | 405.0 | 627200.000 | 4536000.000 | 800.00 | 405.00 |
| 2 | 112.0 | 100.0 | 11200 | 1544.0 | 405.0 | 17292800 | 4536000 | | |
| 3 | 38.0 | 810.0 | 30780 | 131.0 | 405.0 | 4032180 | 12465900 | | |
| 4 | 1300.0 | 100.0 | 130000 | 800.0 | 405.0 | 104000000 | 52650000 | | |
| 5 | 38.0 | 810.0 | 30780 | 1469.0 | 405.0 | 45215820 | 12465900 | | |
| Total | | | 213960 | | | 171168000 | 86653800 | | |

# Lifting Gears Calculation

| No. | Ordinat Relative to COG |  | A*X^2 | A*Y^2 | A*X*Y | $I_{X0}$ | $I_{Y0}$ | $I_X$ | $I_Y$ | $I_{XY}$ |
|---|---|---|---|---|---|---|---|---|---|---|
|  | X | Y |  |  |  |  |  |  |  |  |
|  | mm | mm | mm4 | mm4 | mm3 | mm4 | mm4 | mm4 | mm4 | mm4 |
| 1 | -744.00 | 0.00 | 6199603200 | 0 | 0 | 9333333.333 | 11707733.33 | 9333333.333 | 6.211E+09 | 0 |
| 2 | 744.00 | 0.00 | 6199603200 | 0 | 0 | 9333333.333 | 11707733.33 | 9333333.333 | 6.211E+09 | 0 |
| 3 | -669.00 | 0.00 | 13775927580 | 0 | 0 | 1682896500 | 3703860 | 1682896500 | 1.378E+10 | 0 |
| 4 | 0.00 | 0.00 | 0 | 0 | 0 | 108333333.3 | 18308333333 | 108333333.3 | 1.831E+10 | 0 |
| 5 | 669.00 | 0.00 | 13775927580 | 0 | 0 | 1682896500 | 3703860 | 1682896500 | 1.378E+10 | 0 |
|  |  |  |  |  |  |  |  | 3502126333 | 8.5E+10 | 0 |

**F.5 In-plane Bending**

$I_y$ = $\Sigma$ Ig + $\Sigma$ (A x x'$^2$)
= 8.500E+10 mm^4

$S_y$ = Iy / (Xcog)
= 1.063E+08 mm^3

Inplane Moment M = Py * h1
= 809455276.8 N.mm

Allowable In-plane Bending Stress Fb = 0.66 x fyield
= 234.3 MPa

In-plane Bending Stress fip = M / $S_y$
= 7.618 MPa

Unity Check = **0.033** < 1 **…Accepted**

**F.6 Out-of-Plane Bending**

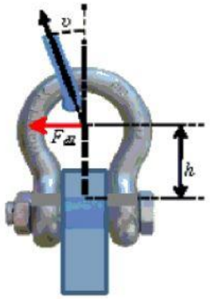
Sx = Ix / (Ycog)
= 4377657.9 mm^3 = 71.7370 m$^3$

5% of static sling force will be applied, as per API 20th edition section 2.4.2.

5% of sling force Fop = 0.05*P

# Lifting Gears Calculation

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 5.502E+05 | N | | |
| Moment arm length | h2=Hsh/2 | = | 475 | mm | | |
| Out-of-plane Moment M | Mop | = | Fop*h2 | | | |
| | | = | 2.613E+08 | N.mm | | |
| Allowable out-of-plane Bending Stress | fop | = | 0.75 x fyield | | | |
| | | = | 266.25 | MPa | | |
| Out-of-plane bending stress | | = | M / $S_x$ | | | |
| | | = | 59.7 | MPa | | |
| Unity Check | | = | **0.224** | | < 1 | **…Accepted** |




<u>Axial Tensile Stress</u>

| | | | | | | |
|---|---|---|---|---|---|---|
| Allowable tensile stress | Ft | = | 0.6 x Fy | | | |
| | | = | 213 | MPa | | |
| Axial Tensile Force ($P_z$) | | = | 1.093E+07 | N | | |
| Tensile Area ($A_s$) | | = | 2*(((rm-dh/2)*tm)+2*((Rc-dh/2)*tc)) | | | |
| | | = | 2.140E+05 | mm^2 | | |
| Axial Tensile Stress | | = | Pz / As | | | |
| | fa | = | 51.1 | MPa | | |
| Unity Check | | = | **0.24** | | < 1 | **…Accepted** |

<u>Combined Axial Tension and Bending</u>

| | | | | | | |
|---|---|---|---|---|---|---|
| Unity Check | UC | = | $f_a / F_t + f_{ip} / F_b + f_{op} / F_b$ | | | |
| | | = | 0.24 + 0.0 + 0.224 | | | |
| | | = | **0.497** | | < 1 | **…Accepted** |

**Horizontal Direction (Main Plate)**

| | | | | | |
|---|---|---|---|---|---|
| Allowable shear stress | = | 0.4 x fyield | | | |
| | = | 142.0 | MPa | | |
| Shear force, max(Py, Fop) | = | 1.265E+06 | N | | |
| Shear Area (As) | = | 2.140E+05 | mm^2 | | |
| Shear stress | = | Py / As | | | |
| | = | 5.9 | MPa | | |
| Unity Check | = | Shear Stress / Allowable Shear Stress | | | |
| | = | **0.042** | | < 1 | **…Accepted** |

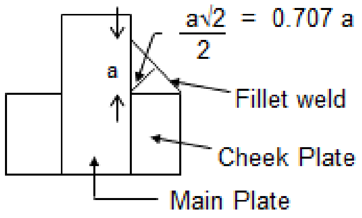
# Lifting Gears Calculation

**F.7 Von Misses Stress**

| | | | | | | |
|---|---|---|---|---|---|---|
| Von Misses Stress | $\sigma$ | = | $(fx^2 + fy^2 + 3fs^2)^{0.5}$ | | | |
| where: | | | | | | |
| total stress in x-dir. | fx | = | 58.71 | MPa (due to in-plane moment and tension) | | |
| total stress in y-dir. | fy | = | 59.70 | MPa (due to out of plane moment) | | |
| shear stress | fs | = | 5.91 | MPa (due to Pv) | | |
| | $\sigma$ | = | 84.353 | MPa | | |
| Allowable stress | $\sigma a$ | = | 0.75x Fy | | | |
| | | = | 266.25 | MPa | | |
| Unity Check | $\sigma/\sigma a$ | = | **0.317** | | < 1 | **...Accepted** |

**G. Welding Sizing**

**<u>Weld of cheek plate to main plate</u>**




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Weld type : E70XX electrode with Fv | Fexx | = | 311.4 | MPa | | | |
| Allowable Shear Stress for Fillet Weld is the lesser of : | | | | | | | |
| | Fsw | = | 0.6*(1/2√2)*Fexx | | | | |
| | | = | 66.1 | MPa | | | |
| Allowable Shear Stress | | = | **66.1** | MPa | | | |
| | | = | | | | | |
| Load at Check Plate | Pcp | = | Ps*(tc/(2*Tc+tm)) | | | | |
| | | = | 3668004.4 | N | | | |
| Effective weld length | lw | = | half perimeter of cheek plate | | | | |
| | | = | 1696.5 | mm | | | |
| Minimum required fillet Size, tw=Pcp/(Fsw*lw) | twr=a | = | 32.73 | mm | | | |
| Size of fillet welds: Min 0.7 x Thk Cheek Plate | | | | | | | |
| Min 0.7 x Thk Cheek Plate | | = | 70.0 | mm | | | |
| Max Thk Cheek Plate-2mm | | = | 98.0 | mm | | | |
| Used fillet weld size | tws | = | 70.0 | mm | < twr | 32.73 mm | **...Accepted** |

# Lifting Gears Calculation