“Structural design of helicopter landing platform for super-yacht ”

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Master Thesis

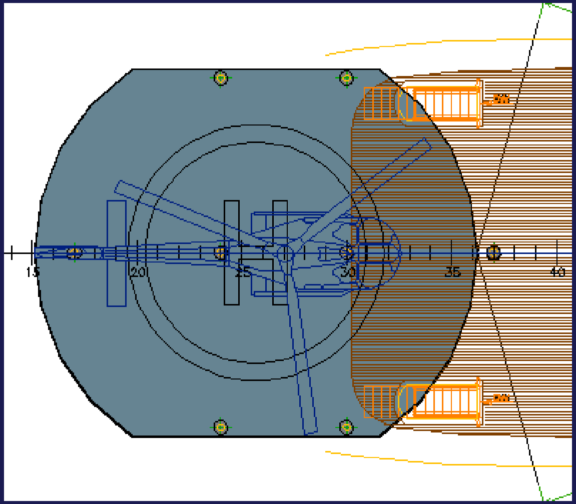
presented in partial fulfillment
of the requirements for the double degree:
“Advanced Master in Naval Architecture” conferred by University of Liège
"Master of Sciences in Applied Mechanics, specialization in Hydrodynamics, Energetics and Propulsion” conferred by Ecole Centrale de Nantes

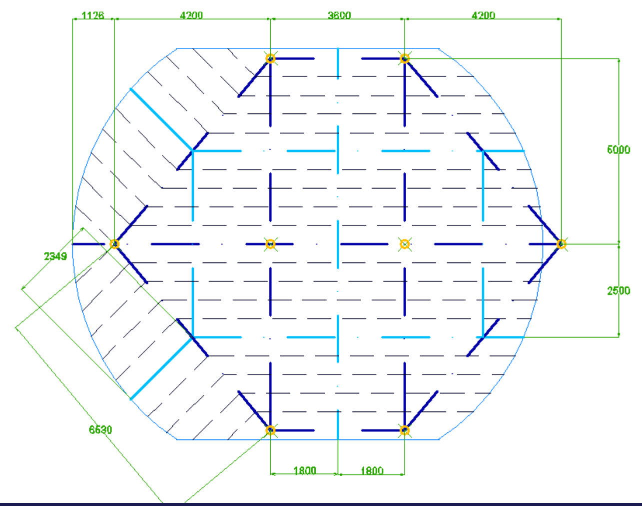
developed at "La Spezia" University of Genoa
in the framework of the

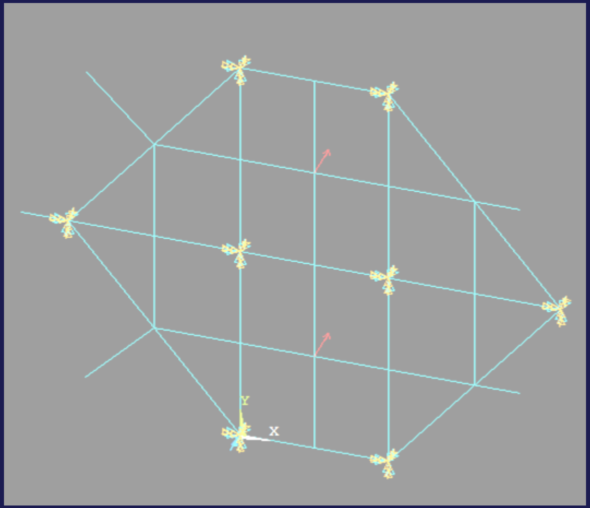
Erasmus Mundus Master Course in
“Integrated Advanced Ship Design”

Supervisor : Prof. Dario Boote
Reviewer: Prof. Zbigniew Sekulski

La Spezia, January 2013







General Structure

Summary

Design

- Purpose
- Location requirements
- Space conflicts
- Aesthetical implications
- Helicopter comparison

- Helicopter – Structure interaction
- Plate
- Secondary stiffeners
- Primary stiffeners
- Columns
- Brackets & detail design

Validation in Ansys

Design purpose

Occasional

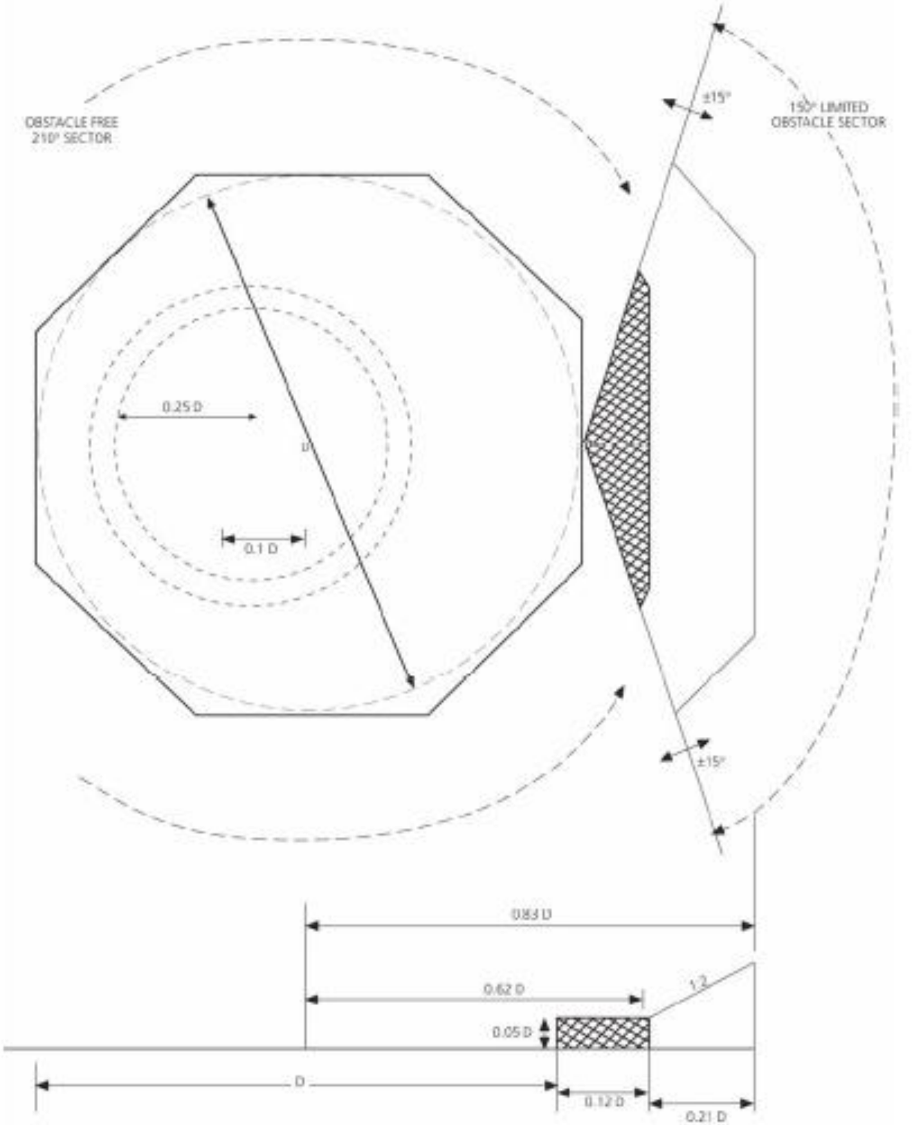
- Emergency landing
- Touch and go

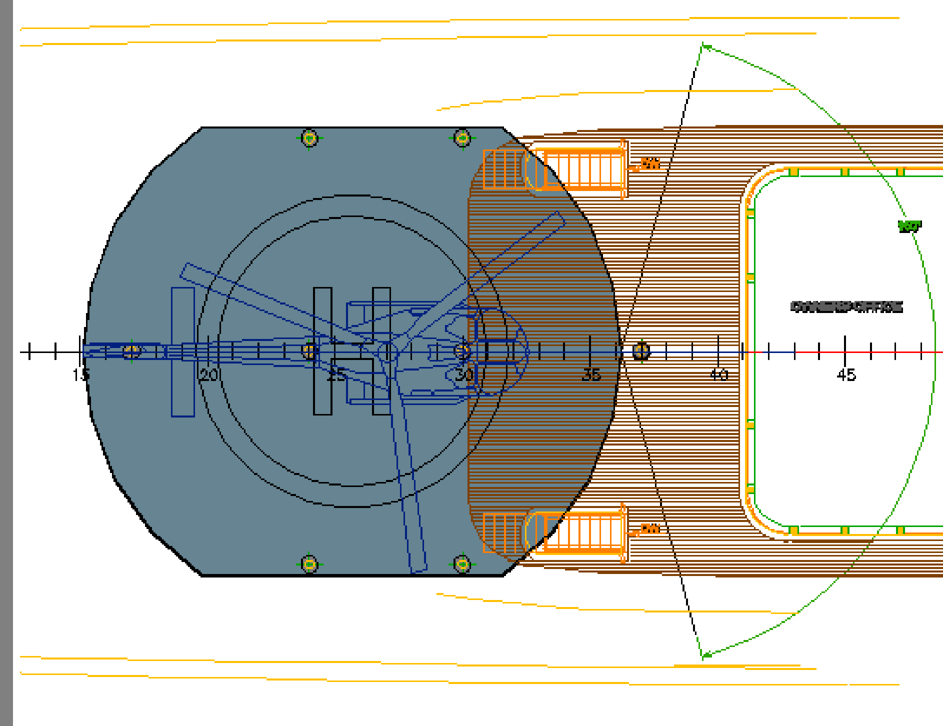
Private use

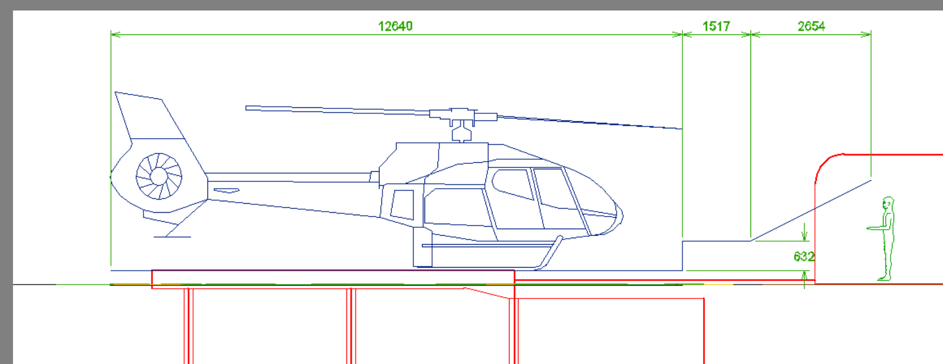
- No requirements
- Operates at his risk
- Smaller dimensions

Commercial use

- Fully in compliance with Large Yacht Code 3
- Used for transferring guests
- Sufficiently large to contain the whole helicopter







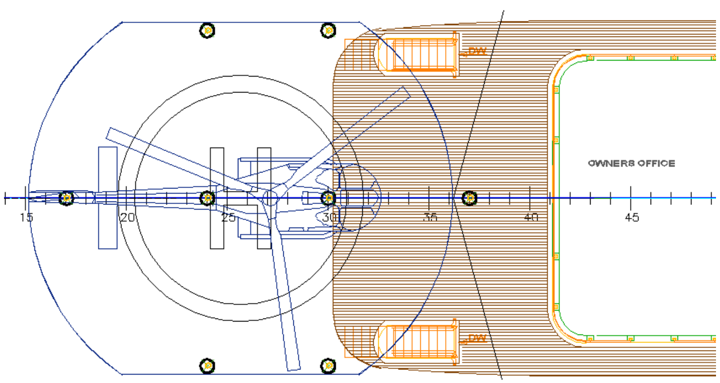
Limited Obstacle Free Sector

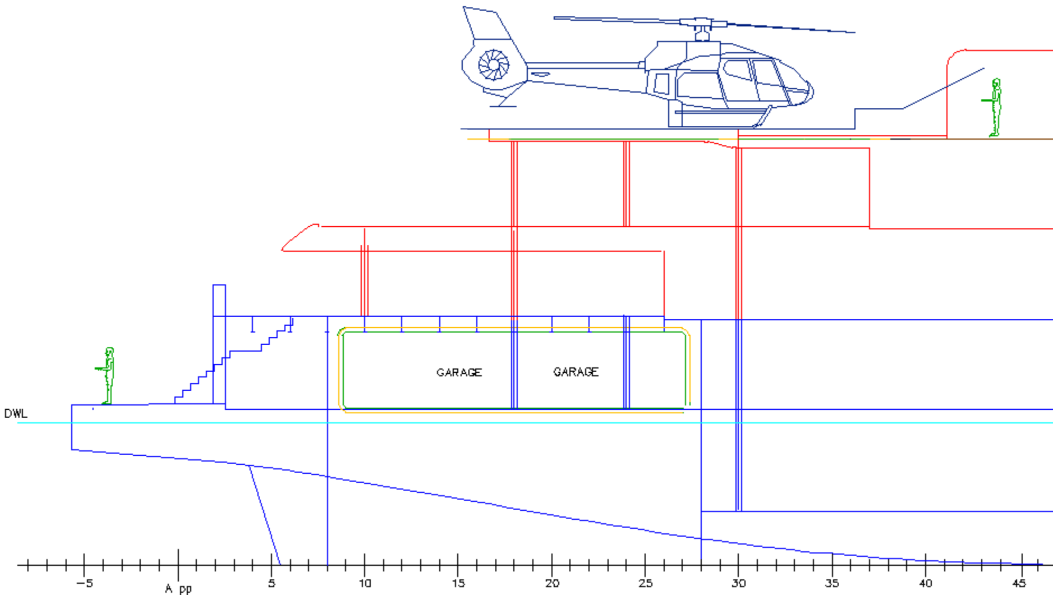
One of the biggest conflicts was the location of the garage exits and the desired pillars

A second conflict was the location of the entrance for the stairs

A third conflict was the owners office, with the limited obstacle free sector

Space conflicts



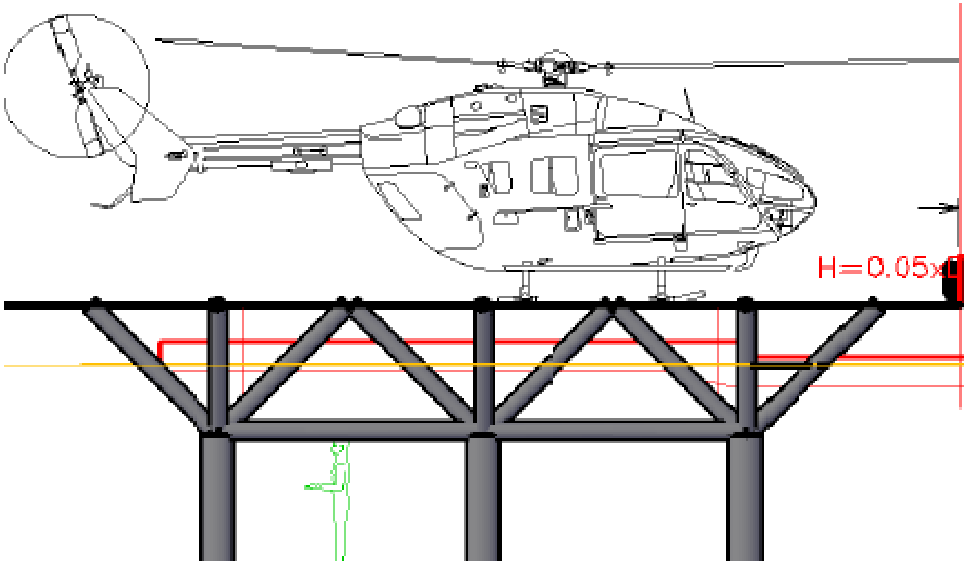


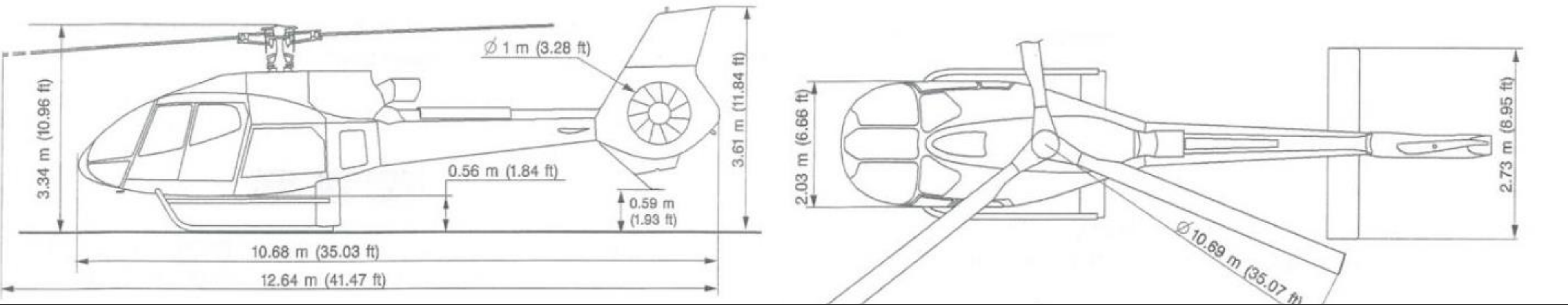
Aesthetical implications

The first helicopter selected was the EC145 with double engine. The Maximum Take-Off Mass require a big platform.

A second Helicopter where finally selected after further analysis.

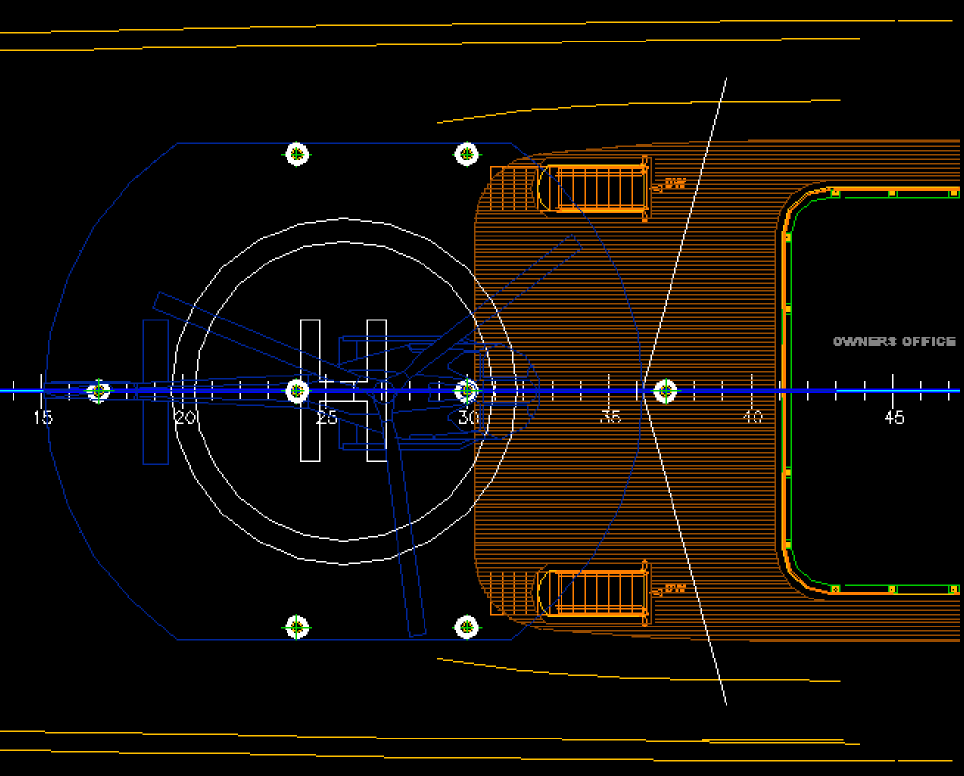
Proposal for the Eurocopter 145

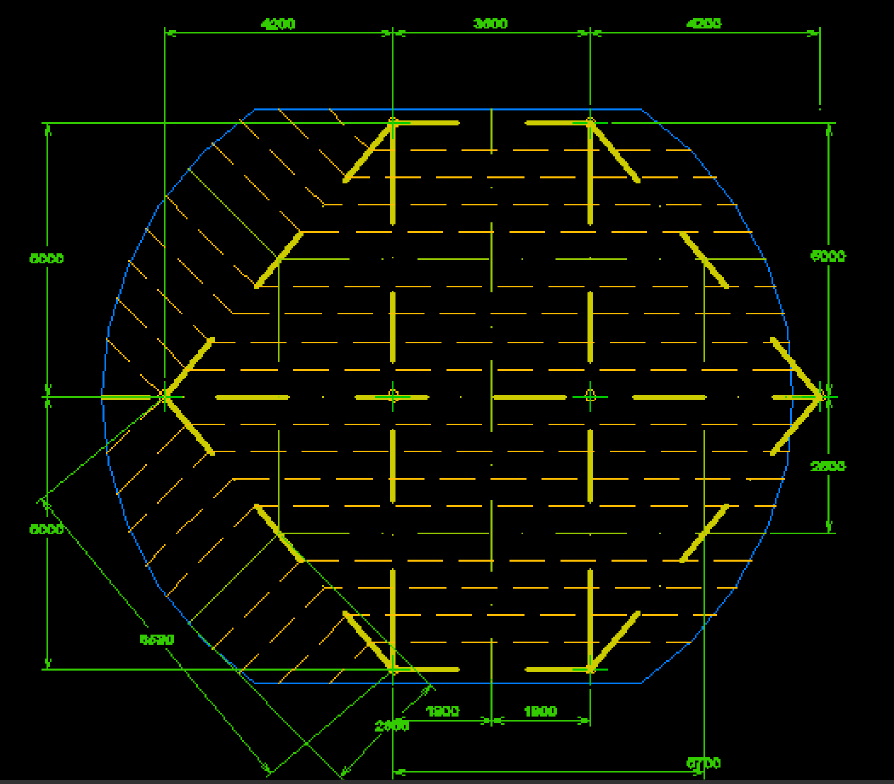




Helicopter comparisons

Type	D value (m)	Perimeter 'D' marking	Rotor diameter (m)	Max weight (kg)	't' value	Landing net size
Eurocopter EC120	11.52	12	10.00	1715	1.7	Not required
Bell 206 B3	11.96	12	10.16	1451/1519	1.5	Not required
Bell 206 L4	12.91	13	11.28	2018	2.0	Not required
Bell 407	12.61	13	10.66	2268	2.3	Not required
Eurocopter EC130	12.64	13	10.69	2400	2.4	Not required
Eurocopter AS350B3	12.94	13	10.69	2250	2.3	Not required
Eurocopter AS355	12.94	13	10.69	2600	2.6	Not required
Eurocopter EC135	12.10	12	10.20	2720	2.7	Not required
Agusta A119	13.02	13	10.83	2720	2.7	Not required
Bell 427	13.00	13	11.28	2971	3.0	Not required
Eurocopter EC145	13.03	13	11.00	3585	3.6	Not required





General structure

With all the previous requirements the final arrangement for the structure is presented:

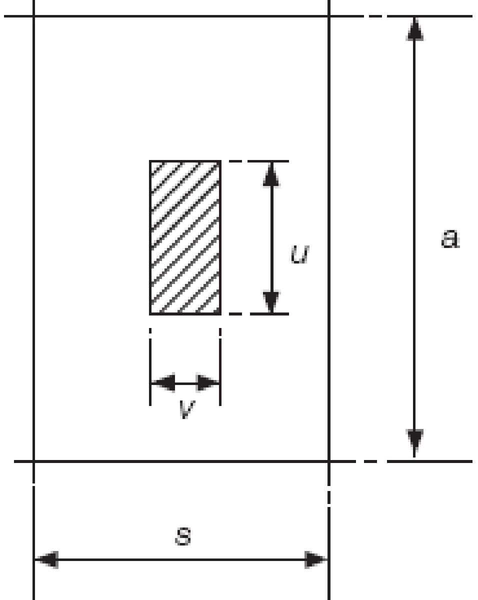
Plate → Blue

Secondary Stiffener → Orange

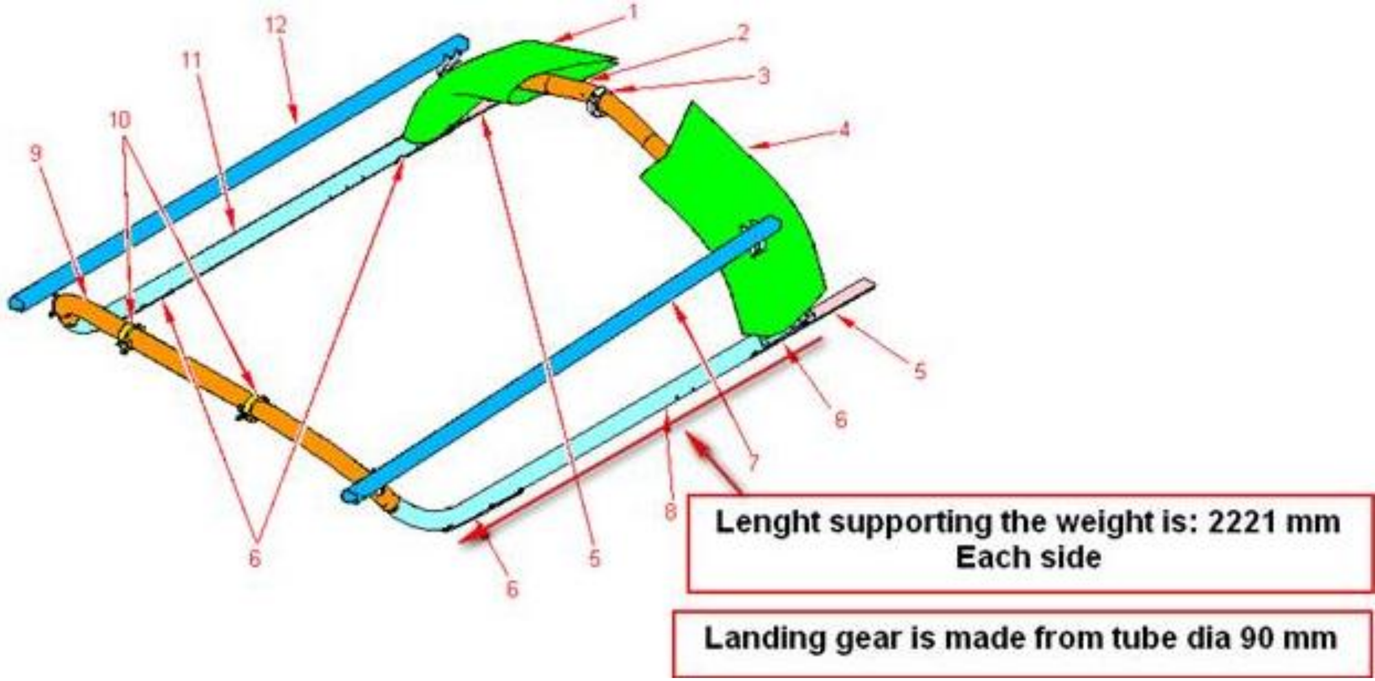
Primary Stiffener → Green

Main Beam → Yellow

Pillars → White

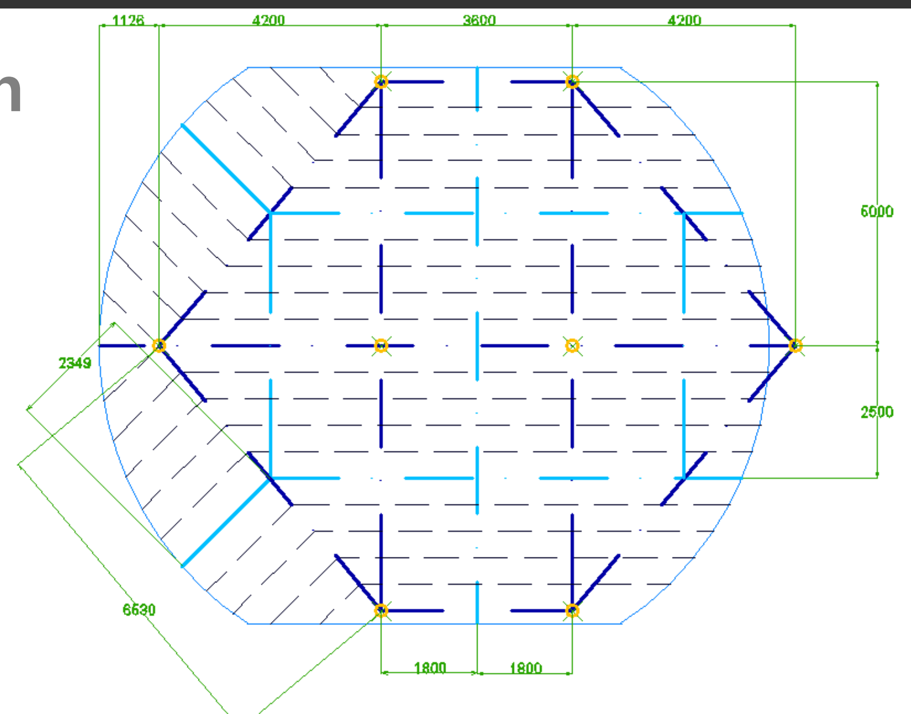


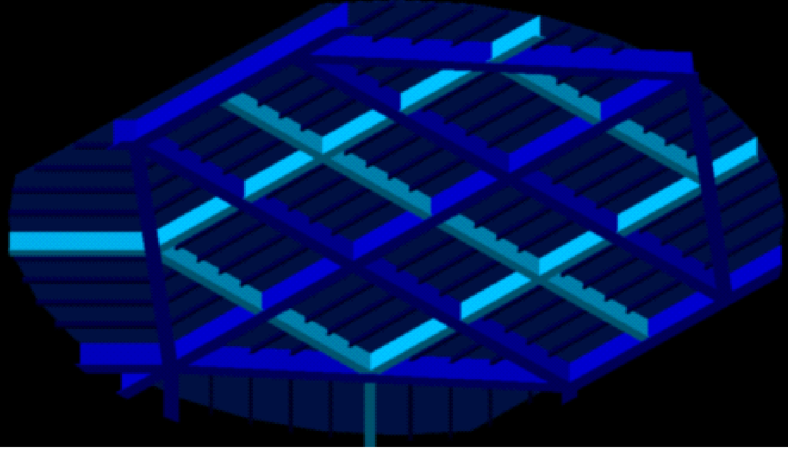
s and *a* are panel dimensions, in mm
u and *v* are print dimensions, in mm

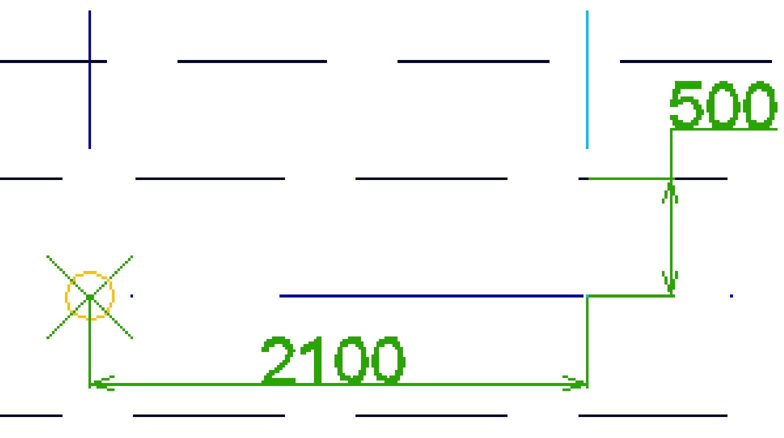


Helicopter – Structure interaction

The structure of the primary members is designed to work connected with the landing gear minimizing the plate thickness and secondary stiffeners requirements.







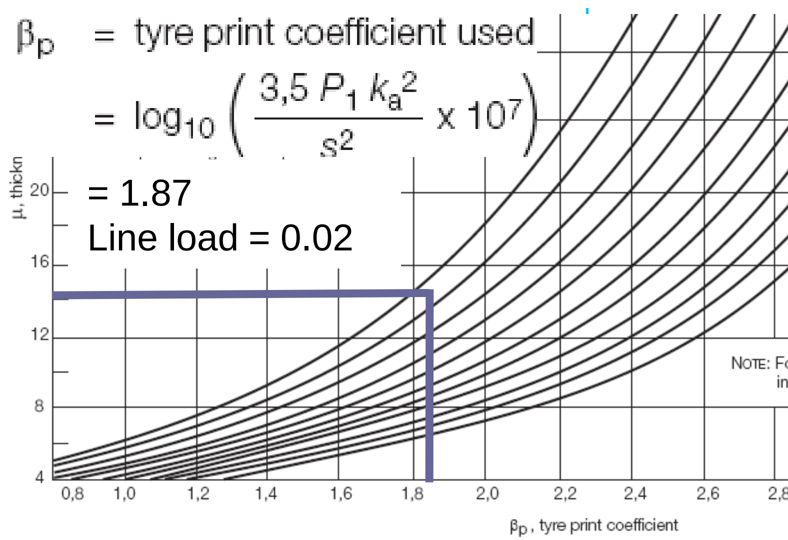


Plate thicknes by rules calculation

Ph = the maximum all up weight of the helicopter

= 2.4 tonnes

Pw = landing load on the tyre print, in tonnes

= 1.2 tonnes

γ = a location factor = 0.6

s = secondary stiffener spacing = 500mm

a = panel vertical dimension = 2100mm

φ1 = patch aspect ratio correction factor

= 0.21509434

φ2 = panel aspect ratio correction factor

=0.72805043

φ3 = wide patch load factor = 1

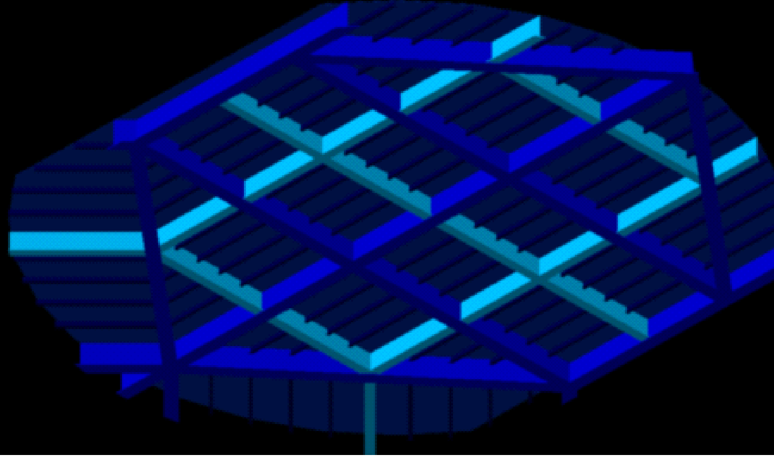
f = 1.15 for landing decks over manned spaces

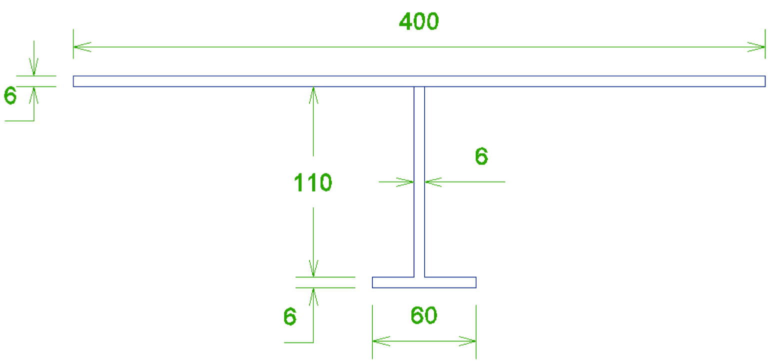
αLgear = thickness coefficient = 15

$$t_p = \frac{\alpha s}{1370\sqrt{k_a}}$$

Thickness plate = 5.47mm

→ 6 mm





Section modulus	61.35	cm^3
	60.75	
The shear sectional area	6.60	cm^2
	0.25	
Inertia	586.50	cm^4
	151.02	

Secondary stiffener by rules calculation

P = maximum effective load per wheel or group of wheels, in kN

= MTOM by 2.5 (emergency case) by 1.3 (Structural response factor) = 38.245935kN

l = overall secondary stiffener length = 2.1m

s = stiffener spacing = 0.5m

d = load area parallel to stiffener axis = 2.221m

E = Young's modulus of elasticity = 275 N/mm2

w = load area perpendicular to stiffener axis = 0.01m

kw = lateral loading factor = 1 for w ≤ s

fσ = limiting bending stress coefficient =1 for Helicopter

fτ = limiting shear stress coefficient taken =1 for Helicopter

fδ = limiting deflection coefficient taken = 625

σa = 0,2% proof stress of material = 125 N/mm2

τa = shear stress of the alloy = 72.16878365 N/mm2

m = d / l = 1.057619048

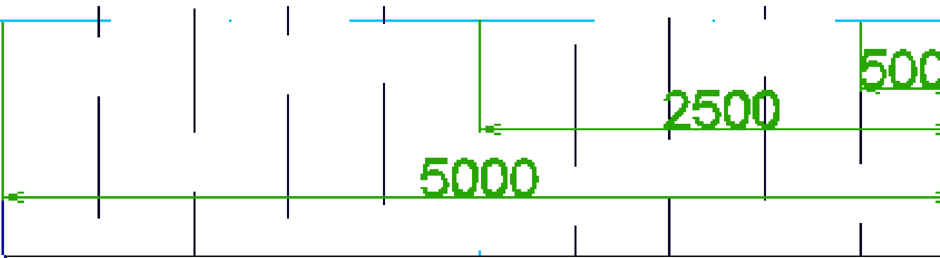
minimal section modulus =60.75266037cm3

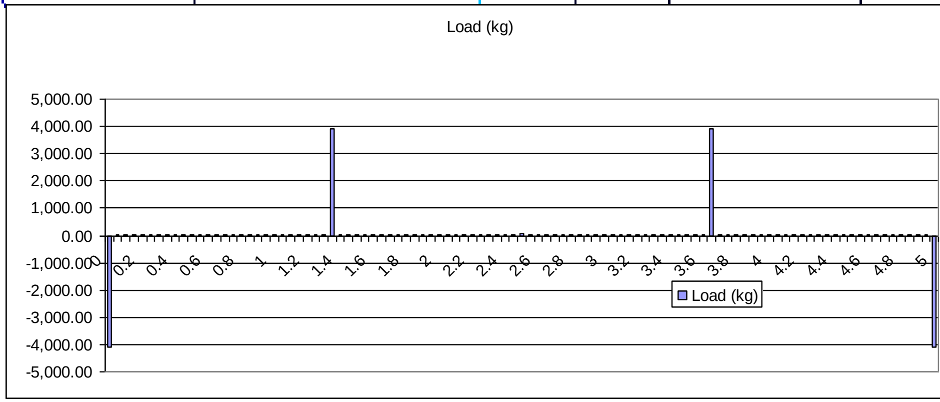
minimal Inertia = 151.018687cm4

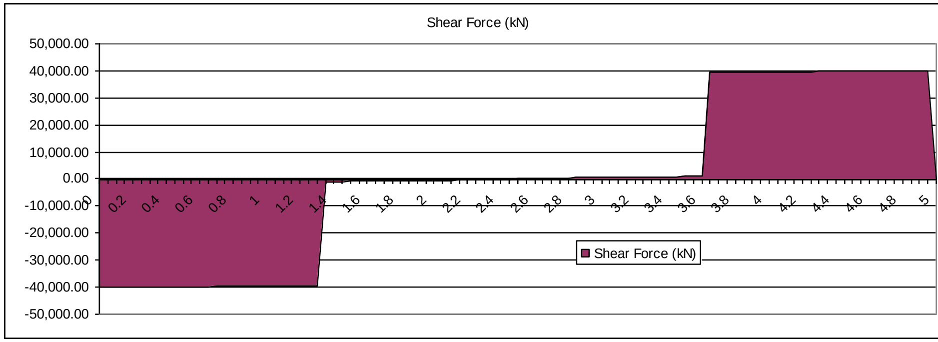
minimal web area = 0.250539749 cm2

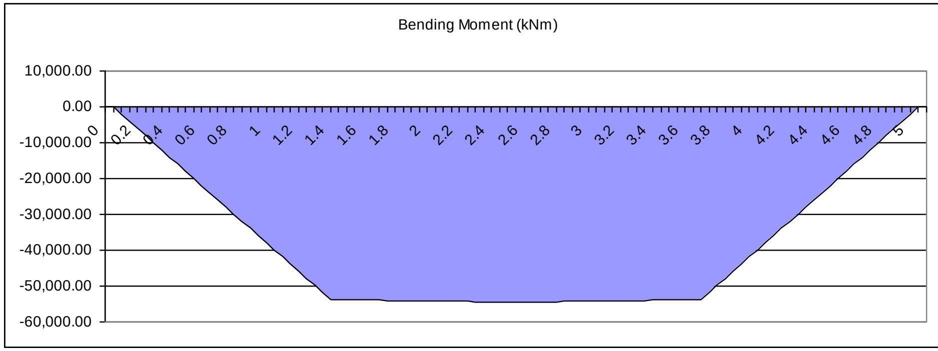
The nominal factor of the effective breadth = 400mm

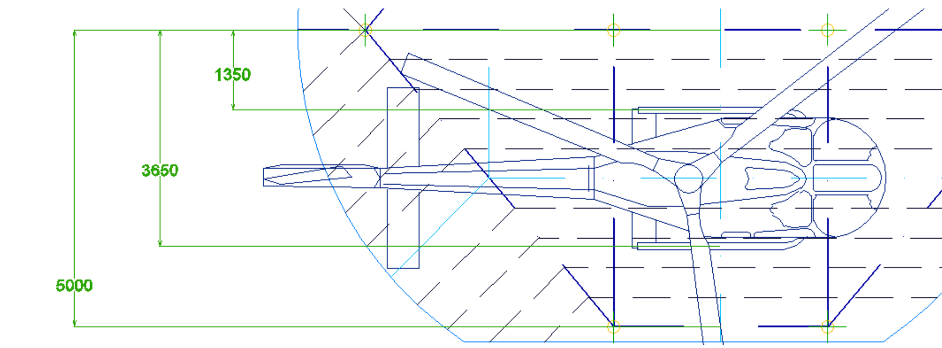
Primary stiffener by direct calculation

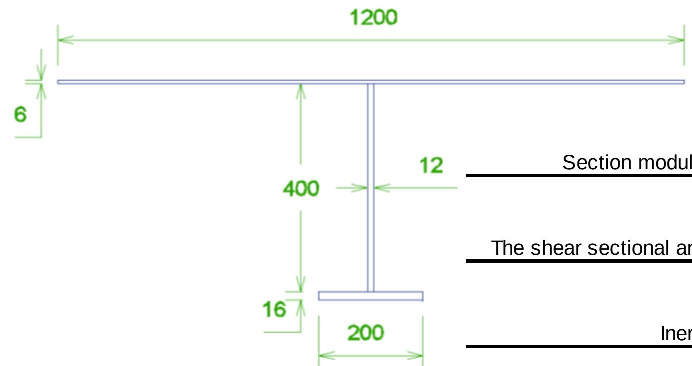












Section modulus 1704.95 cm^3

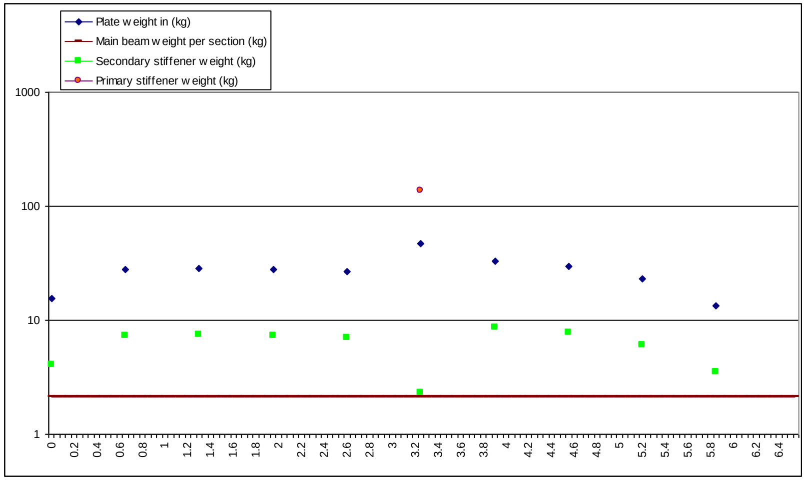
-1665.11

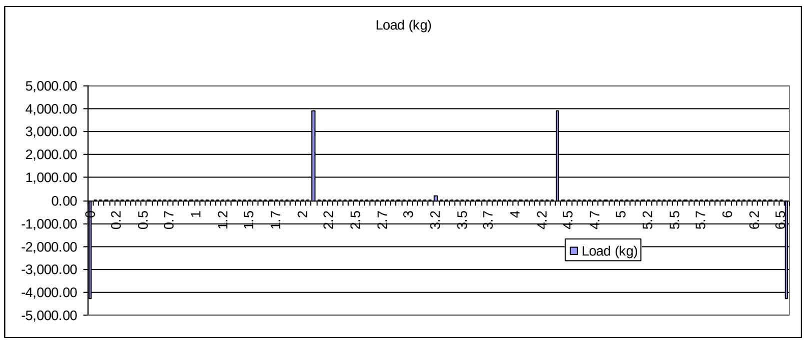
The shear sectional area 48 cm^2

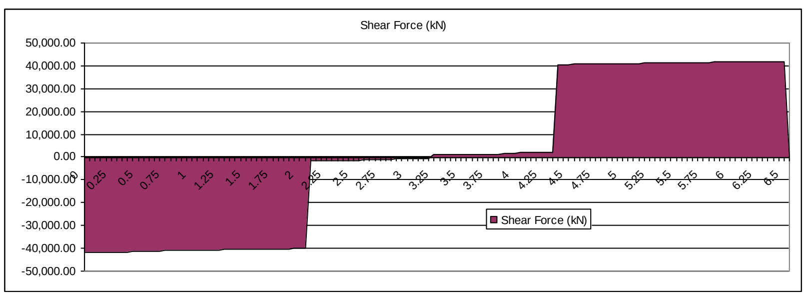
Inertia 45755.42 cm^4

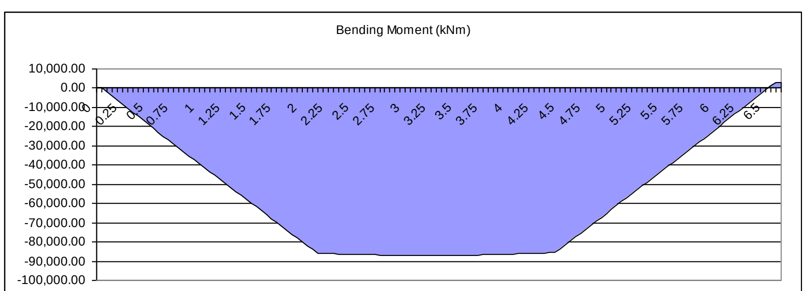
```
Area                  =   15200.
Iyy                   = 0.45755E+09
Iyz                   =-0.43586E-06
Izz                   = 0.87472E+09
Warping Constant      = 0.17812E+13
Torsion Constant      = 0.59901E+06
Centroid Y            =-0.19817E-12
Centroid Z            =   268.37
Shear Center Y        =-0.85909E-08
Shear Center Z        =   413.90
Shear Correction-yy   = 0.41037
Shear Correction-yz   = 0.14164E-11
Shear Correction-zz   = 0.22248
```

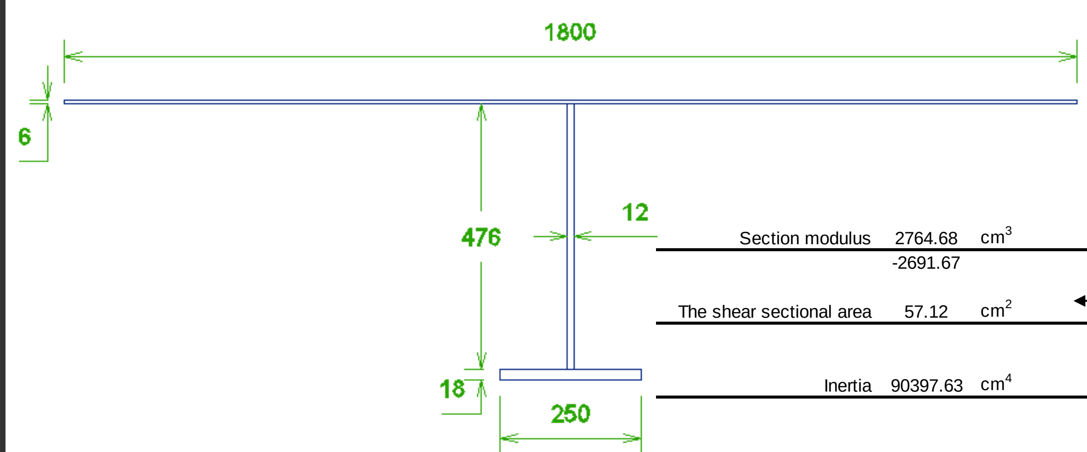
Main beam
by direct calculation

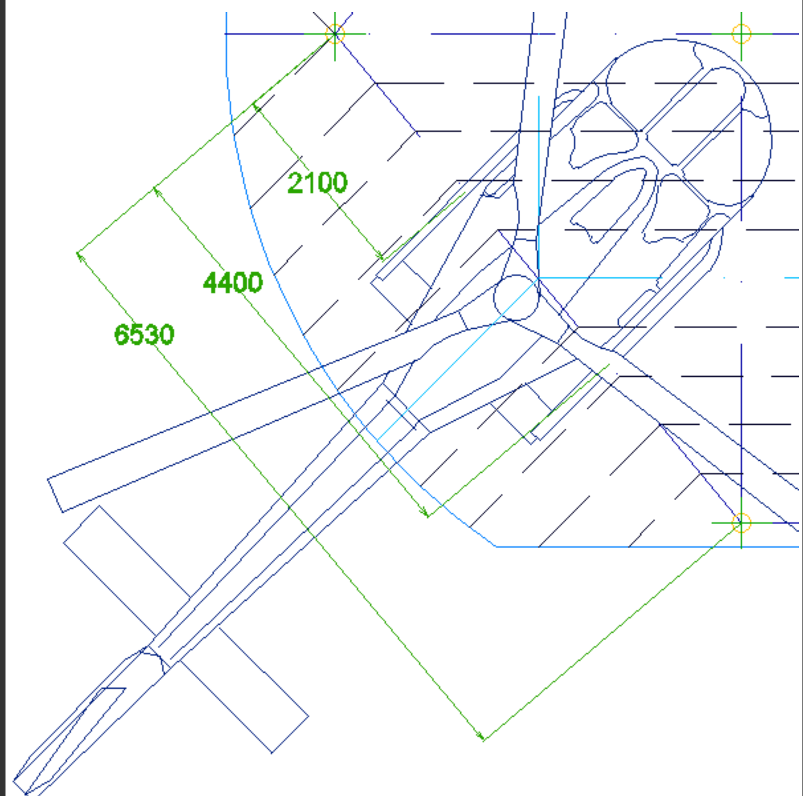




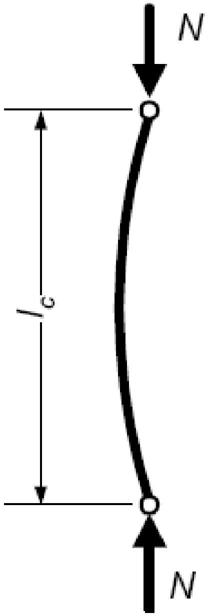


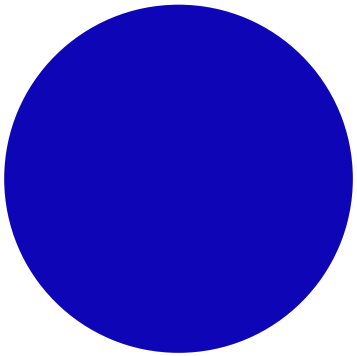






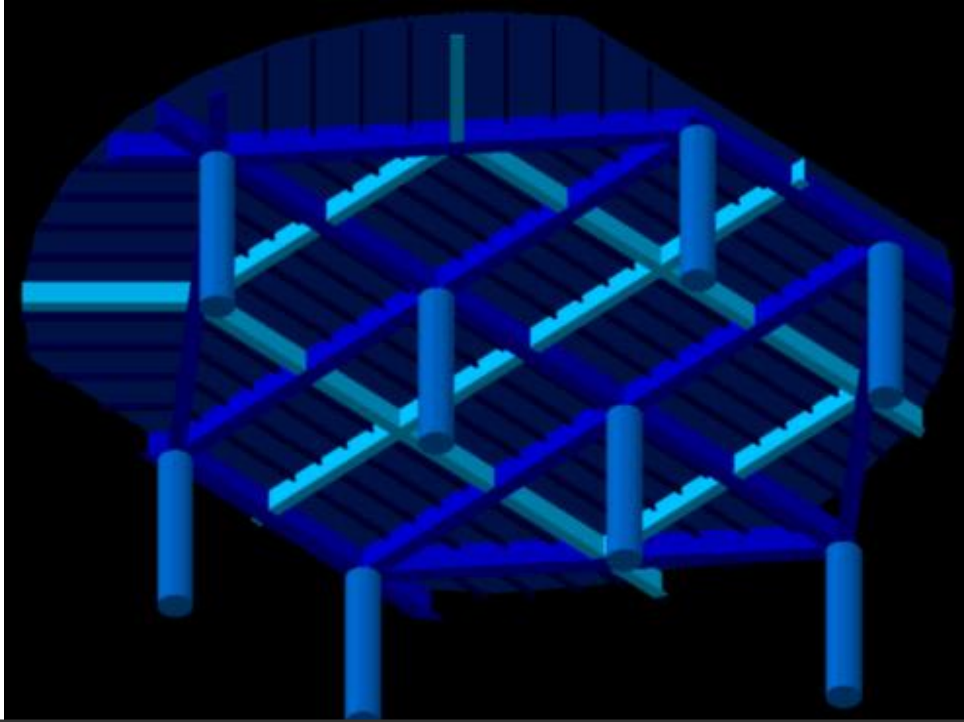

```
Area
  = 21012
Iyy
  = .904E+09
Iyz
  = .217E-05
Izz
  = .294E+10
Warping Constant
  = .554E+13
Torsion Constant
  = 893663
Centroid Y
  = .580E-12
Centroid Z
  = 326.974
Shear Center Y
  = -.139E-07
Shear Center Z
  = 493.056
Shear Corr. YY
  = .439039
Shear Corr. YZ
  = .974E-13
Shear Corr. ZZ
  = .173928
```





A = 0.1985 m²

d = 0.50279 m



Columns

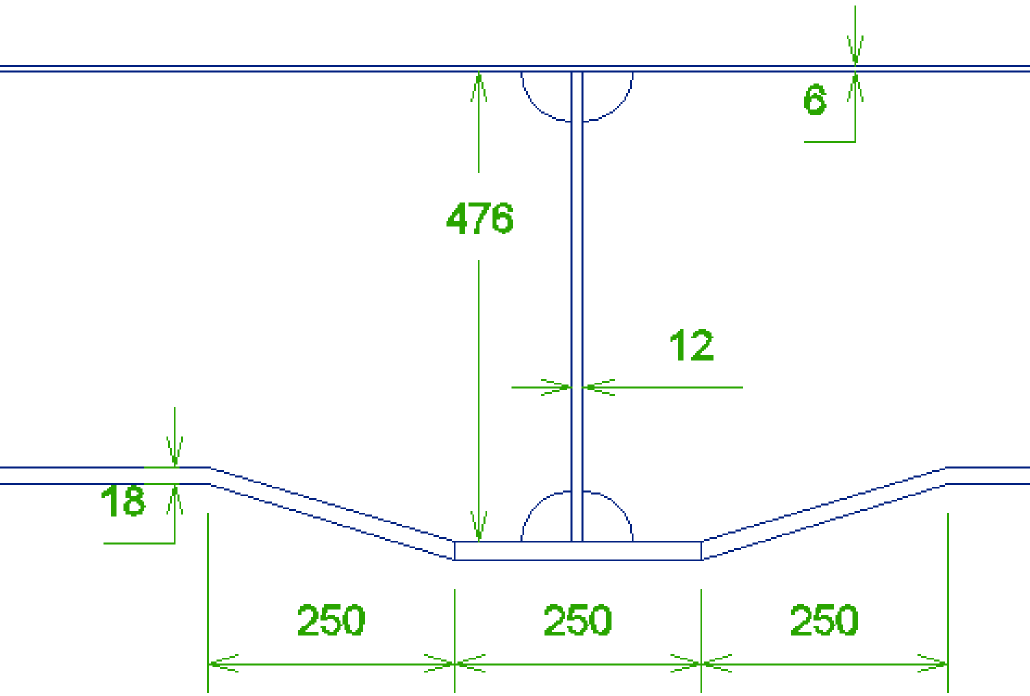
The columns require an effective length of 2500mm and should be designed for a maximum pressure of 43500kN.

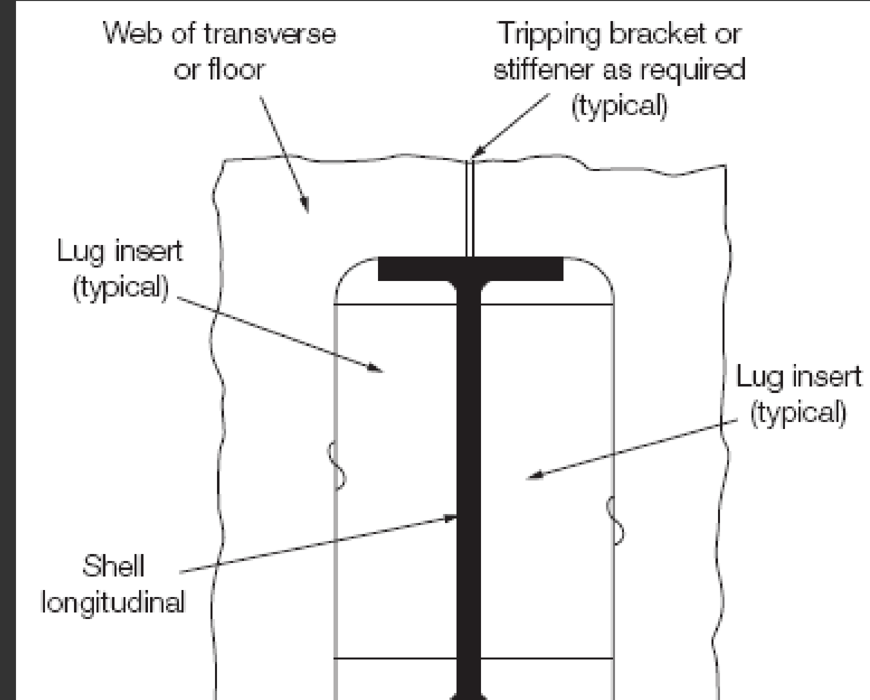
A 6061-T6 aluminium bar.

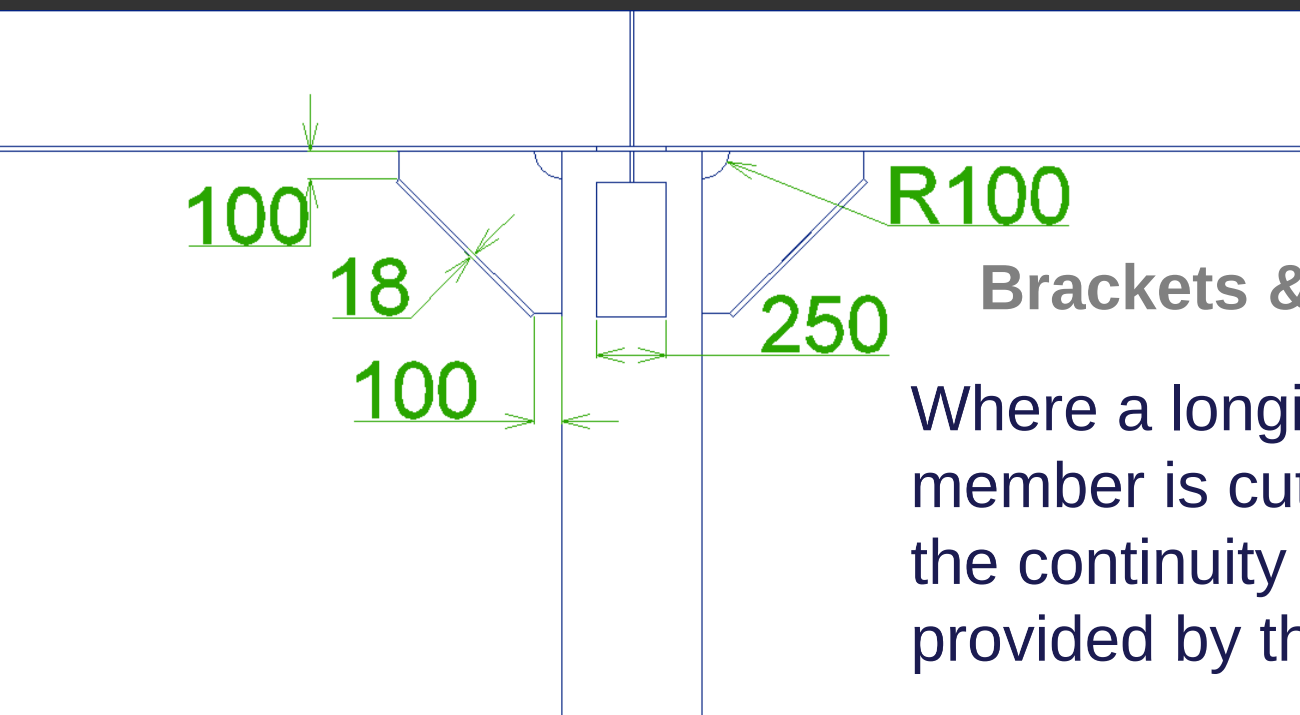
Safety factor material = 1.1

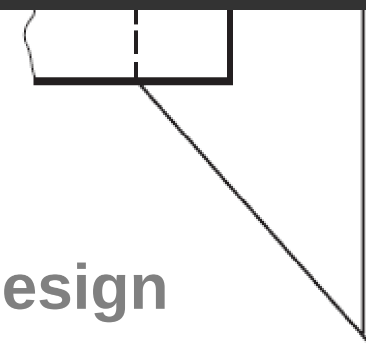
$$\sigma_{all} = \frac{\sigma_Y}{FS_{material}} = 219 \text{ MPa} \rightarrow \frac{P_{des}}{A} \leq \sigma_{all}$$

$d = 502mm$



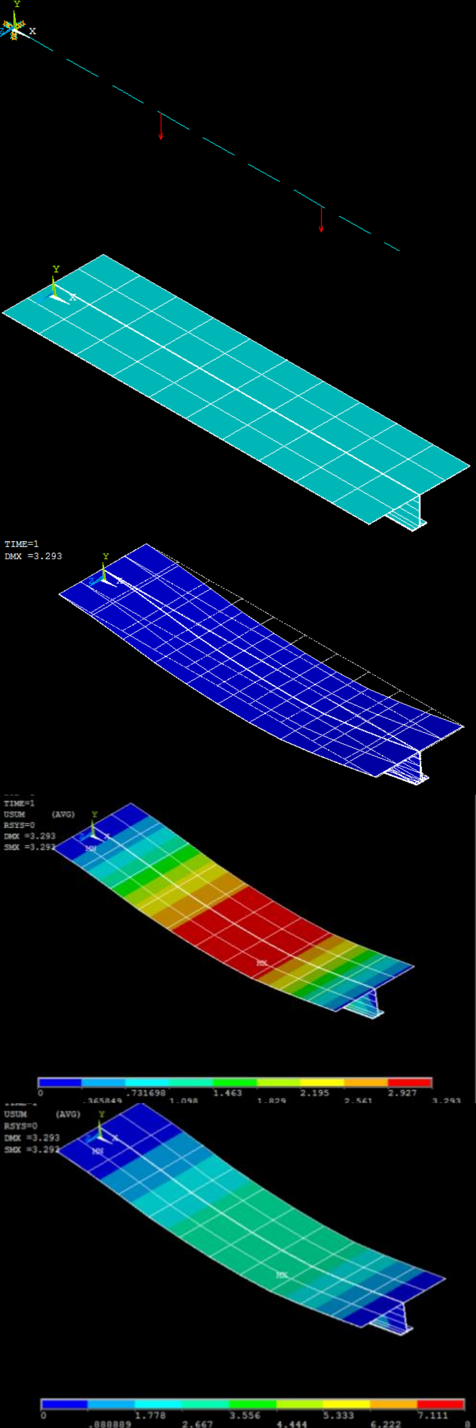


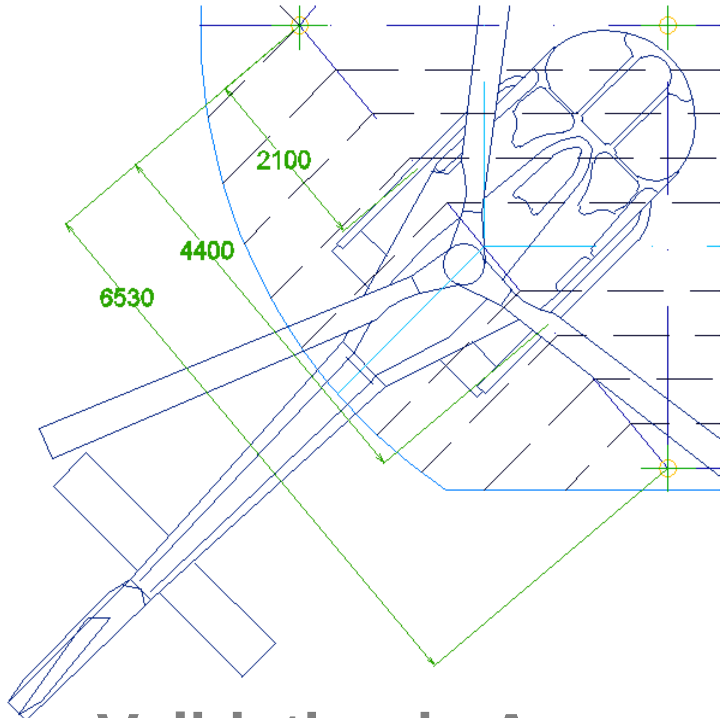




Brackets & detail design

Where a longitudinal strength member is cut at a primary support, the continuity of the strength is provided by the brackets





NODE	UX	UY	UZ	USUM
1	0	0	0	0
2	0	0	-3.56E-08	3.56E-08
3	0	-0.23106	-3.88E-09	0.23106
4	0	-0.56294	-7.77E-09	0.56294
5	0	-0.96785	-1.14E-08	0.96785
6	0	-1.418	-1.49E-08	1.418
7	0	-1.8856	-1.80E-08	1.8856
8	0	-2.3429	-2.11E-08	2.3429
9	0	-2.6339	-2.38E-08	2.6339
10	0	-2.8803	-2.65E-08	2.8803
11	0	-3.0757	-2.84E-08	3.0757
12	0	-3.2137	-3.04E-08	3.2137
13	0	-3.2879	-3.17E-08	3.2879
14	**0**	**-3.2918**	**-3.30E-08**	**3.2918**
15	0	-3.219	-3.37E-08	3.219
16	0	-3.0631	-3.44E-08	3.0631
17	0	-2.6894	-3.47E-08	2.6894
18	0	-2.2411	-3.51E-08	2.2411
19	0	-1.7331	-3.52E-08	1.7331
20	0	-1.1803	-3.53E-08	1.1803
21	0	-0.59759	-3.54E-08	0.59759

Validation in Ansys

This case is the extreme, because it represents an emergency landing, defined as 2.5 times the Maximum Take-Off Mass, in the medium of the largest main beam.

The maximum value of deformation, is located in the node 14, not exactly in the middle, but a little bit moved to the direction of horizontally unrestricted edge.

Conclusions

1. The rules and regulation developments for helideck structure on super-yacht, are not generated as a result of an experience in super-yacht, but as an interpolation of the limits applied for very big ships.

2. The drastically incremented areas used for commercial helideck purposes compared, with the areas used for private helideck purposes, represent dramatically increment in weight and cost for the super yacht

3. The very big structural supports as pillars and beams required for commercial helideck generate a bad aspect of the yacht.

4.The design of the structure is mainly based for a specific helicopter EC130