# LIFTING CALCULATION FOR A NAVAL STRUCTURE

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**Abstract:** *The purpose of this calculation is to estimate the level of the stresses of* a naval *structure, during the lifting operations when the structure is take-up from the shore for mounting on the ship. The following assumptions and limitations were taken into consideration: the values of the weight and the coordinates of the center of gravity of the structure was multiplied by the dynamic amplification factor (DAF), the vertical distance between the structure and hook of the crane was considered, the hook and the gravity weight center must be placed on the same vertical, the weights of the rigging system (slings, shackle, etc.) are not considered.*

**Keywords:** *finite element, lifting, stress*

## 1. Introduction

Offshore structures and other vessels require periodic lifting work for their maintenance and installation. Structures subjected to lifting can be exposed to accidental falls, which must be assessed in relation to the size of the accidental loads, because the risk of falling of the object is considered one of the major risk categories in offshore structures. Based on the structural response, such as stress, deformation and displacement, the results of the analysis methods are compared and their validity is investigated.

In this paper, a methodology that is required to perform the lifting simulation is described.

In general, a marine lifting operation involves lifting of any structure by a crane vessel in the offshore environment. Some of the examples are listed below:

- The lifting of topsides by crane barges to set-up on Jacket structures;
- Lift and removal of offshore assets in de-commissioning phase;
- The lifting of Jackets from transportation barges, to set on the sea bed;
- The lifting of pipelines, subsea assets, modules, etc. for subsea installations;
- Transfer of cargo/passenger between vessels.

It is observed that the mass and geometry of the high load vary depending on the operation. Regardless of size, the fundamental principles of lifting remain the same.

## 2. Loads and safety factors

For any lift, the calculations carried out shall include allowances, safety factors, loads and load effects as described in Ref. [3], Annex F.

**Table 1:** *Factors relevant for lifting design*

| | | Load factors | | | | | Resistance factor | |
|---|---|---|---|---|---|---|---|---|
| | | | | | DF = $(\gamma_p \cdot \gamma_c)$ | | | |
| APPLICATION | TO FIND | $W_{COG}$ | SKL | DAF | $\gamma_p$ | $\gamma_c$ | $\frac{1}{\gamma_e}$ | $\gamma_{Rm}$ |
| Lifting accessories | | | | | | | | |
| Sling design | MBL | X | X | X | X | X | X | X |
| Shackle selection | MBL | X | X | X | X | X | | X |
| Master link/ Forerunner | MBL | | | X | X | X | X | X |
| Check of structural capacity during lifting | | | | | | | | |
| Check of structure capacity | Design capacity | X | X | X | X | X | | X |
| Lifting lug design | Design capacity | X | X | X | X | X | | X |

The model of the structure is considered as loaded by its own weight, W, multiplied by:

-weight contingency factor $W_{CF}$ = 1.1;

-center of gravity envelope factor, $W_{COG}$ = 1.1 for object with a complex weight pattern;

-dynamic amplification factor (DAF), 1.445 for onshore lift;

-skew load factor, SKL = 1.1 for single hook 4 point lift with one spreader bar and 2 pairs of slings (Fig. 1);

-design factor, DF = 1.48 for main elements which are supporting the lift point, acc. to Ref. [3], Annex F, Table F.4 (see Table 1).

**Table 2:** *Design factor*

| ELEMENT CATEGORY | $\gamma_P$ | $\gamma_C$ | DF ($\gamma_P \cdot \gamma_C$) |
|---|---|---|---|
| Lifting points including attachments to object<br>Single critical elements supporting the lifting point | 1,34 | 1,25 | 1,68 |
| Lifting equipment (spreader bar, shackles, slings etc) | 1,34 | 1,25 | 1,68 |
| Main elements which are supporting the lift point | 1,34 | 1,10 | 1,48 |
| Other structural elements of the lifted object | 1,34 | 1,0 | 1,34 |

The lifting scheme for a pair of slings is shown in Fig. 1 and the forces are calculated as follows:

$$P_{LP} = \frac{WLL \cdot W_{COG} \cdot SKL \cdot DAF \cdot L_2}{(L_1 + L_2)} \quad (1)$$

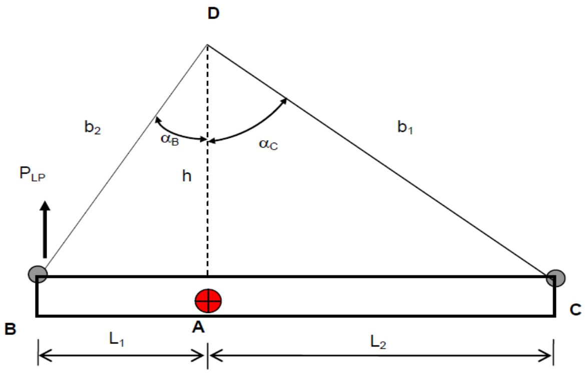



**Figure 1:** *2 point lift – vertical reaction, $P_{LP}$*

Because $L_1$=$L_2$, the vertical reaction $P_{LP}$ may be expressed by the equilibrium equation as follows:

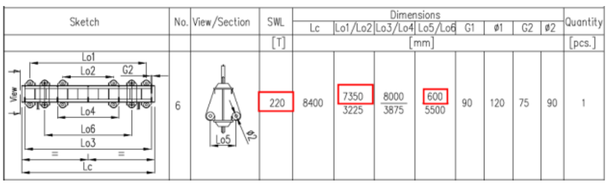
The mass and the COG of the part of the helideck structure have been considered according to technical specification:

W=61250kg,

$WLL = W \cdot W_{CF}/2 = 61250 \cdot 1.1/2 = 33687$kg – for each pair of slings.

$P_{LP} = WLL \cdot W_{COG} \cdot SKL \cdot DAF/2$ – the vertical force for each sling

$P_{LP}$=288909N



| Sketch | No. | View/Section | SWL | Dimensions | | | | | | | | Quantity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Lc | Lo1/Lo2 | Lo3/Lo4 | Lo5/Lo6 | G1 | ø1 | G2 | ø2 | |
| | | | [T] | [mm] | | | | | | | | [pcs.] |
| | 6 | | 220 | 8400 | 7350/3225 | 8000/3875 | 600/5500 | 90 | 120 | 75 | 90 | 1 |



**Figure 2:** *Spreader beam used*

**Table 3:** *List of slings*

| LIST SLINGS ON THE FLOATING CRANE | | | | | |
|---|---|---|---|---|---|
| NO. | SWL | LEINGHT | PCS. | DIAMETER ROPE | TYPE |
| 1 | 130 T | 6m | 2 | 84 mm | GROMMET |
| 2 | 90 T | 11m | 2 | 90 mm | SLING Z |
| 3 | 90 T | 6m | 2 | 90 mm | SLING Z |
| 4 | 76 T | 9m | 2 | 66 mm | GROMMET |
| 5 | 76 T | 7m | 4 | 66 mm | GROMMET |
| 6 | 75 T | 20 m | 2 | 66 mm | GROMMET |
| 7 | 75 T | 15m | 4 | 66 mm | GROMMET |
| 8 | 75 T | 10m | 4 | 66 mm | GROMMET |
| 9 | 75 T | 4m | 4 | 60 mm | GROMMET |
| 10 | 65 T | 6 m | 4 | 60 mm | GROMMET |
| 11 | 65 T | 8 m | 4 | 60 mm | GROMMET |
| 12 | 34 T | 12 m | 6 | | BELT Z |
| 13 | 32 T | 12 m | 5 | 40 mm | BELT Z |
| 14 | 32 T | 4 m | 4 | 40 mm | BELT Z |
| 15 | 25 T | 15 m | 4 | 36 mm | BELT Z |
| 16 | 10 T | 6 m | 6 | 32 mm | SLING Z |
| 17 | 10 T | 5 m | 4 | 32 mm | SLING Z |
| 18 | 10 T | 3 m | 4 | 32 mm | SLING Z |
| 19 | 6,3 T | 10 m | 4 | | SLING Z |

According to the lifting sling sets (Table 3) and the spreader beams (Fig. 2) existing and used, usually, in Shipyard, the following loading scheme has been considered:

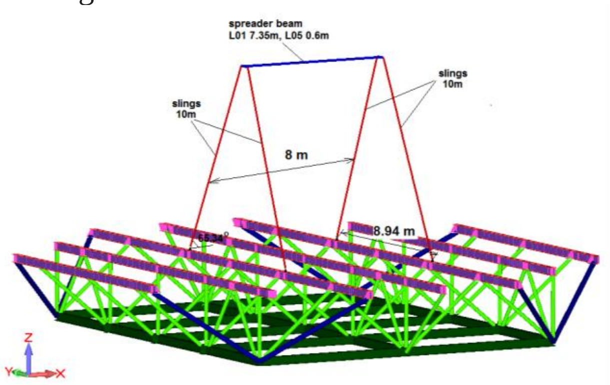



**Figure 3:** *Lifting scheme of the considered structure*

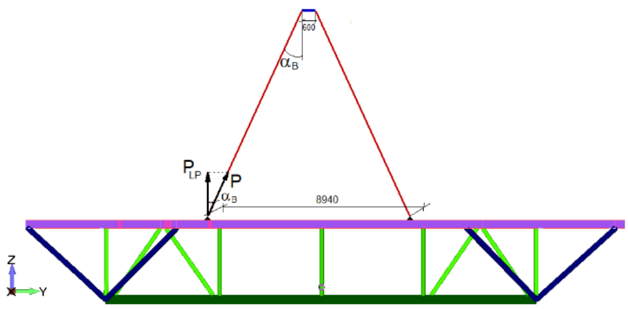



**Figure 4:** *Lifting scheme of the considered structure – transversal view*

The resulting in-plane angle $\alpha_B$ = 24.28° and the force along in-plane sling are:

$P = P_{LP} \cdot DF/\cos(\alpha_B) = 288.9 \cdot 1.48/\cos(24.28°)$

P = 389.8kN

The resulting out-of-plane angle $\gamma_B$ = 1.86° and the force along sling that was introduced in the FE model are:

$P_p = P/\cos\gamma_B$ = 389.8/cos(1.86°)

*$P_p$=389.6kN*

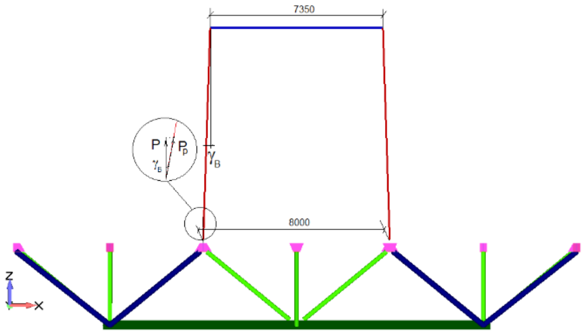



**Figure 5:** *The lifting scheme of considered structure – Longitudinal View*

For the equilibrium of the system an acceleration $a_z = -g \cdot W_{CF} \cdot W_{COG} \cdot SKL \cdot DAF \cdot DF = -27.94\ m/s^2$ has been adopted and introduced in Femap as body acceleration.

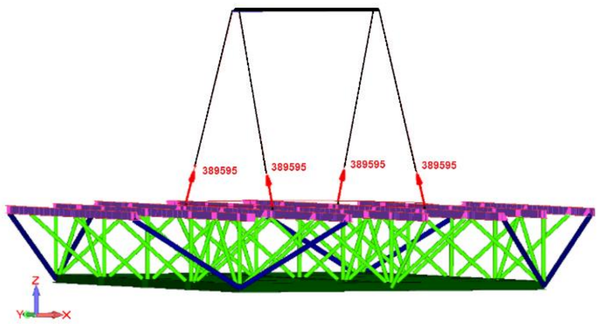
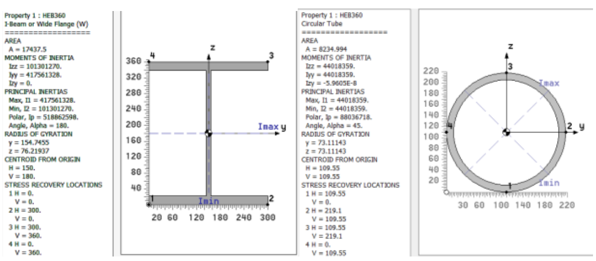



**Figure 6:** *The forces loads along sling for lifting operation*

## 3. Model description

The finite element model has been developed according to basic construction drawings. Bar elements with different properties have been used to model the considered structure (see Fig. 7). The finite element model has been developed according to the basic construction drawings and the potential modifications following the analysis will have to be implemented in them.

Material used for modeled structure is AH36 with 355 N/mm$^2$ yielding stress.



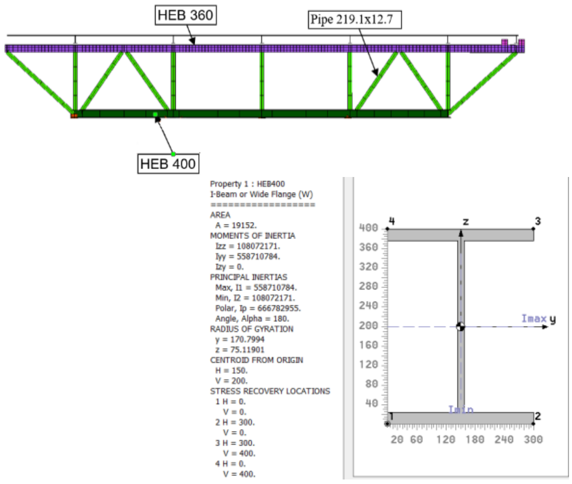



**Figure 7:** *3D FE Model*

## 4. Results

The material resistance factor for structural members is $\gamma_{Rm} = 1.15$.

The allowable stress is:

$\sigma_a = 355/1.15 = 308\ N/mm^2$

The maximum effective Von Mises stress in the platform structure plate elements is $\sigma_{VM} = 165\ N/mm^2 < 308\ N/mm^2$ (see Fig. 8) and in the bar elements $\sigma_{comb} = 82 N/mm^2 < 308 N/mm^2$ (see Fig. 9).

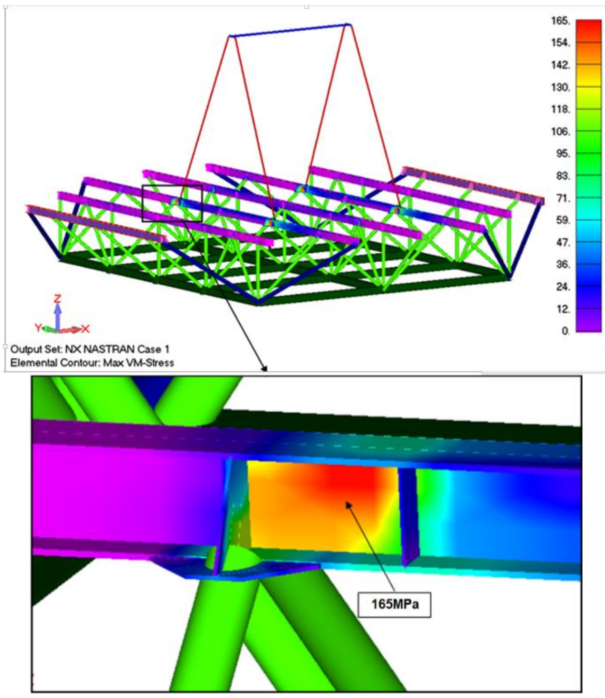



**Figure 8:** *Considered structure - Plate Von Mises stress, lifting conditions*

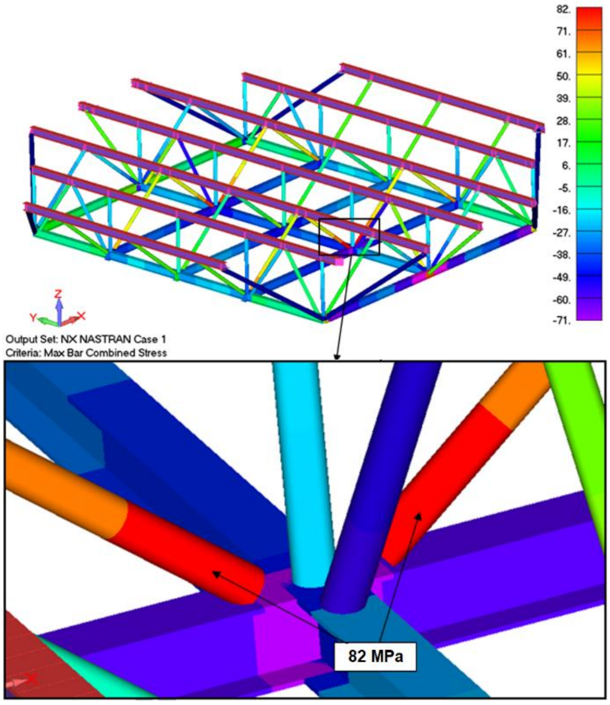



**Figure 9:** *Considered structure – Max bar comb. stress, lifting conditions*

## 5. References

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