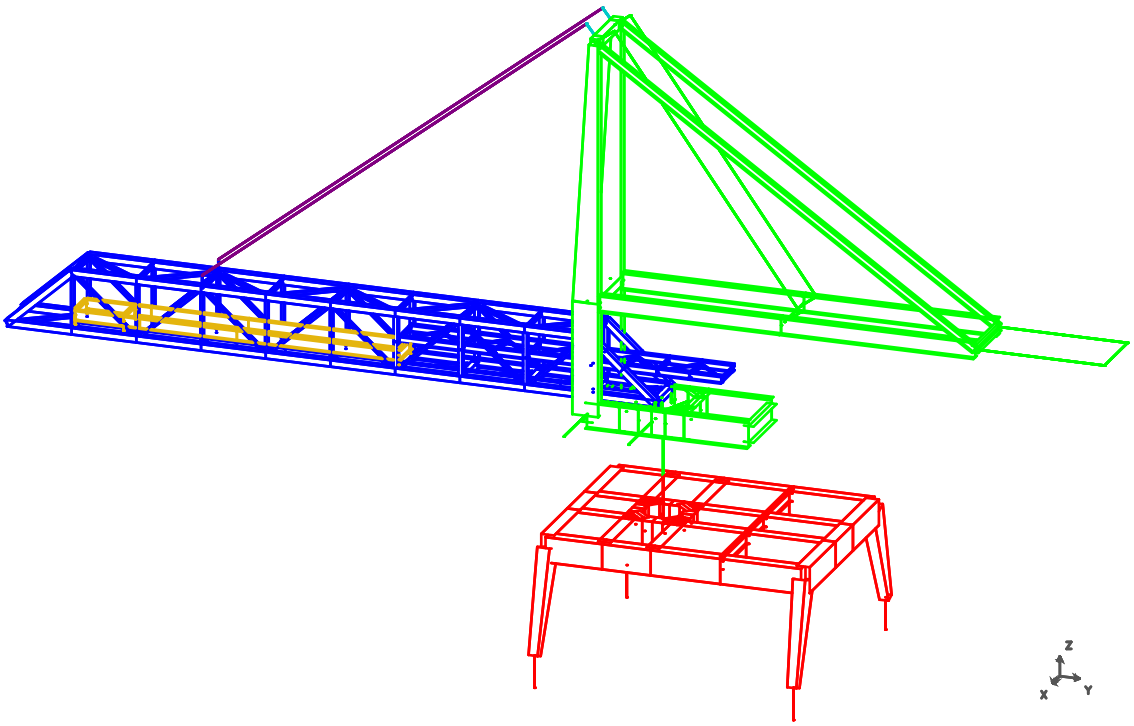
Ship loader example
Version 1

Kühne BSB GmbH



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1 Calculation principles

1.1 Considered standards:

[S1] DIN 15018 part 1, Nov. 1984, Cranes, Principles for steel structures, stress analysis

[S2] FEM 1.001 issue October 1998, cranes steel structures and machinery

[S3] DIN 4114, July 1952, Stahlbau, Stabilitätsfälle (Knickung, Kippung, Beulung), Berechnungsgrundlagen, Vorschriften

1.2 Literature

[L1] Petersen, Christian: Statik und Stabilität der Baukonstruktionen – 2., durchges. Aufl. – Braunschweig; Wiesbaden: Vieweg 1982.

2 General description

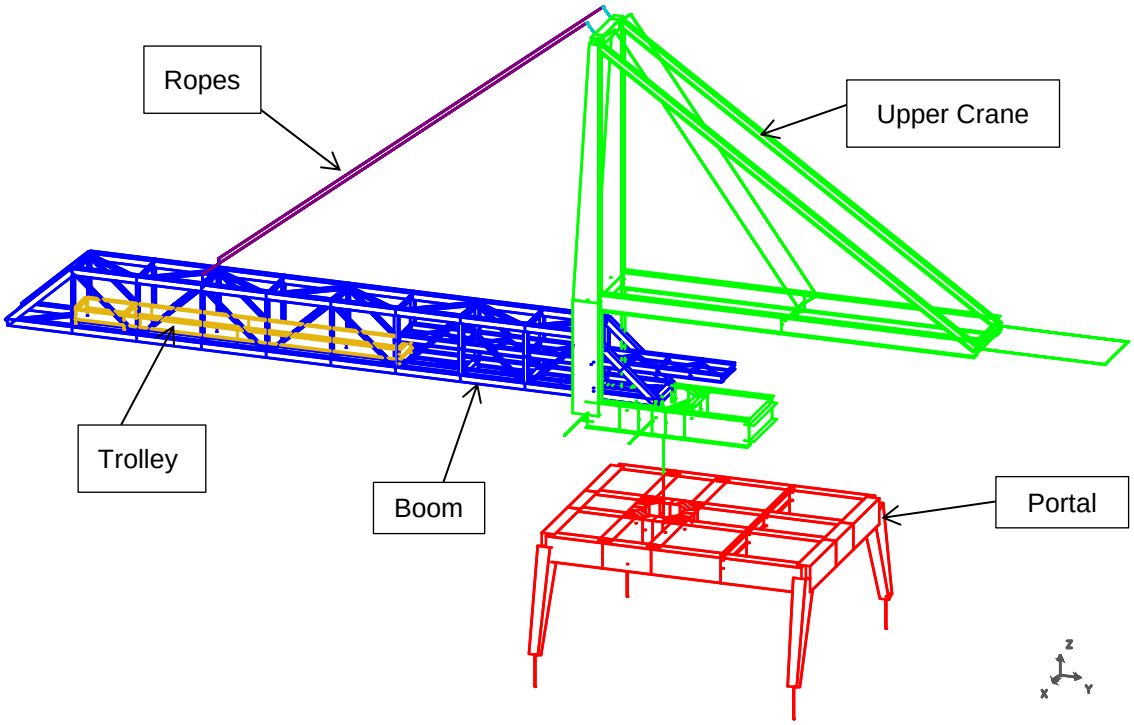


Figure 1: Parts of the ship loader

The ship loader example is a rail mounted machine that is loading ships with bulk material. It consists of a portal, an upper crane on the portal and a boom with a moveable trolley. The loader is fed via a landside conveyor.

This structure is modeled with subsystems in the beam model. The calculation program KRASTA allows for analysis of different situations (moved subsystems or deactivating of some beams) in a single beam model and finding maximum stresses and inner forces across these situations.

2.1 Main dimensions

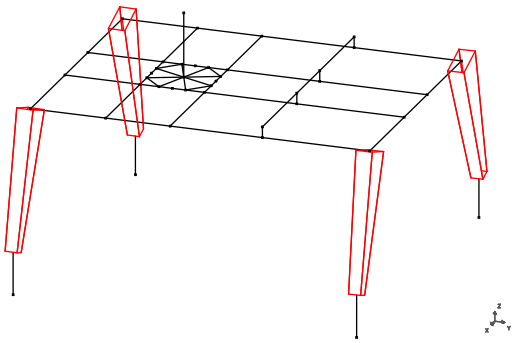
Table 1: main dimensions

Portal rail distance	8.00 m
Portal wheel base	8.00 m
Total height	19.60 m
Boom length	20.00 m
Boom turntables at level	5.50 m

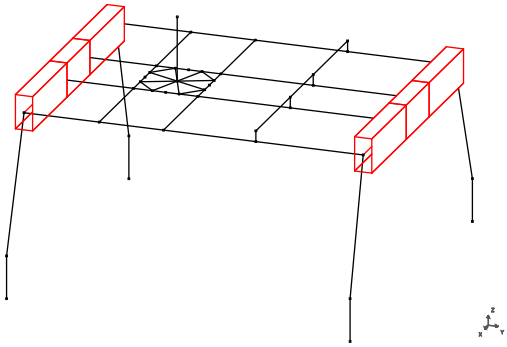
3 Items considered in the structural calculation

Table 2: Items 1-5 (Portal)

	Item	Cross section	Material
Portal	001	Conical at feet: RR 300x300x20. at top: RR_800x400x20.	S235 or equivalent
	002	RR 800x400x20.	S235 or equivalent
	003	RR 800x400x20x15	S235 or equivalent
	004	DT 800x300x20x15	S235 or equivalent
	005	IPE 300_	S235 or equivalent
Upper Crane	006	HEB 800_	S235 or equivalent
	007	HEB 500_	S235 or equivalent
	008	RR 800x300x20.	S235 or equivalent
	009	Conical at feet: RR 300x300x20. at top: RR_800x300x20.	S235 or equivalent
	010	HEB 200_	S235 or equivalent
	011	RR 300x300x20.	S235 or equivalent
Boom	012	RR 200x200x16.0_	S235 or equivalent
	013	RR 200x200x10.	S235 or equivalent
	014	RR 120x120x8.	S235 or equivalent
	015	RR 80x80x6.3.	S235 or equivalent
	016	HEB 200_	S235 or equivalent
	017	IPE 120_	S235 or equivalent
	018	RR 40x40x4.	S235 or equivalent
Trolley	019	IPE 300_	S235 or equivalent
Ropes	020	rigid	



Item 001



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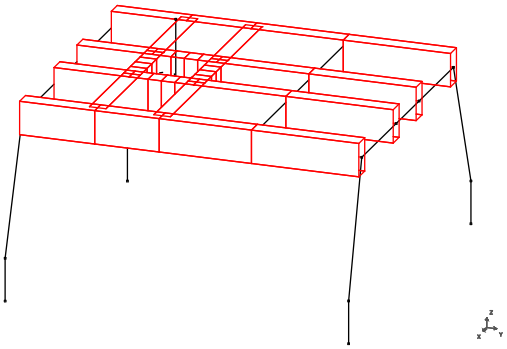

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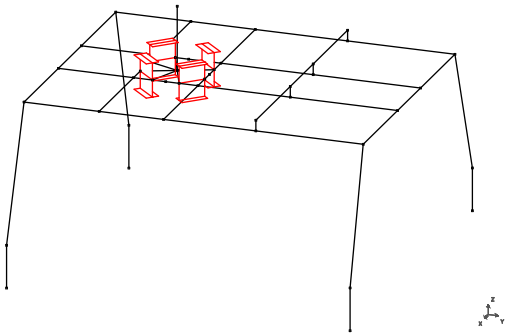

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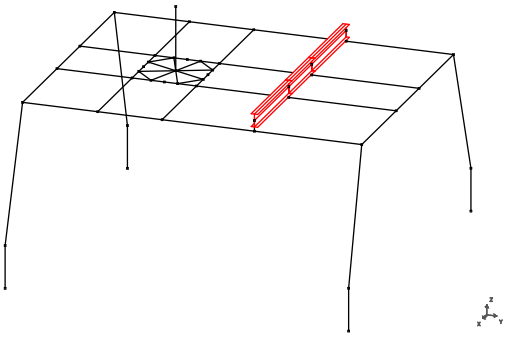
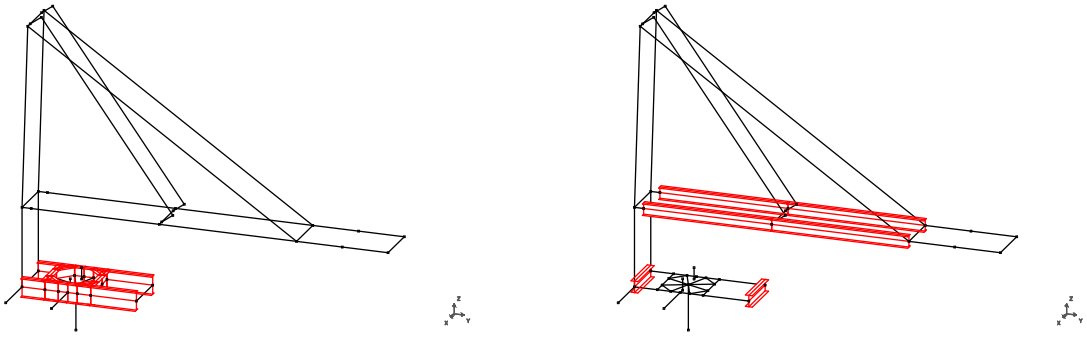
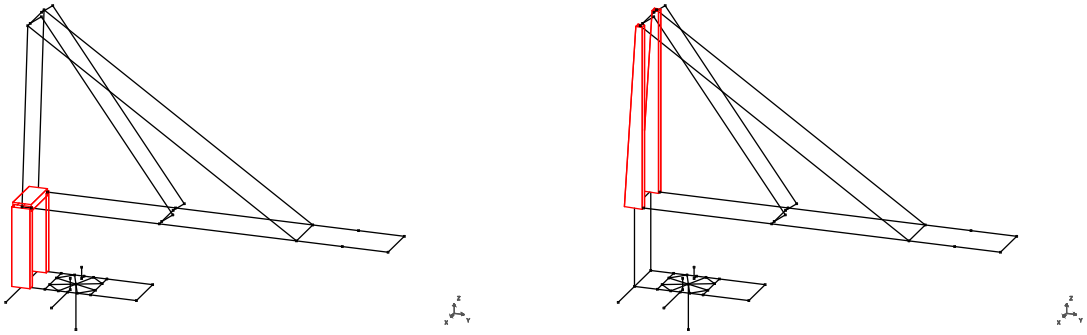


Item 005

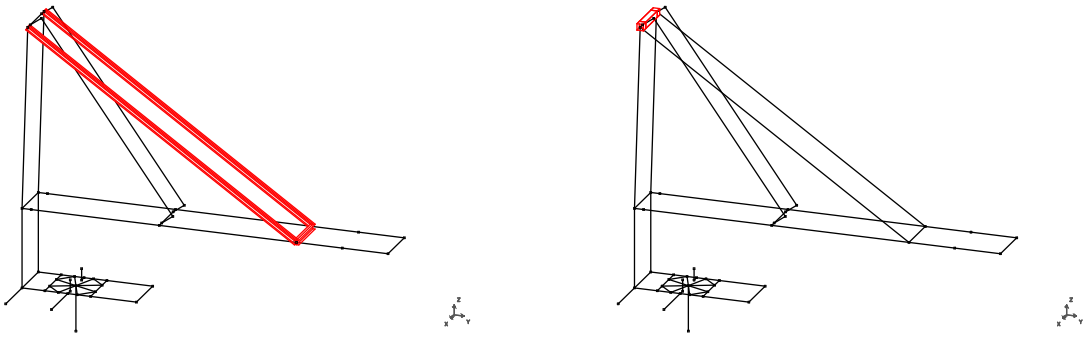
Figure 2: Items 001-005 (Portal)



Item 006 **Item 007**

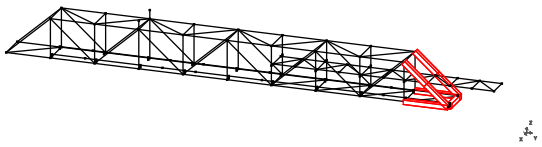


Item 008 **Item 009**



Item 010 **Item 011**

Figure 3: Items 006-011 (Upper Crane)



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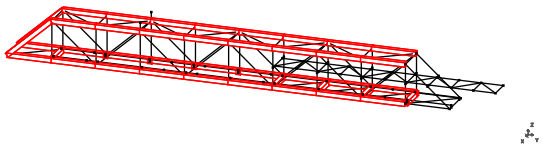

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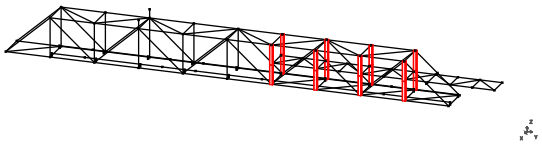

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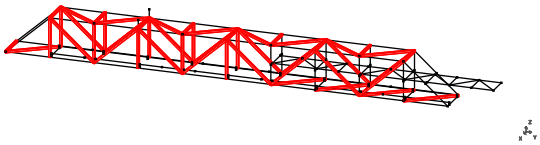

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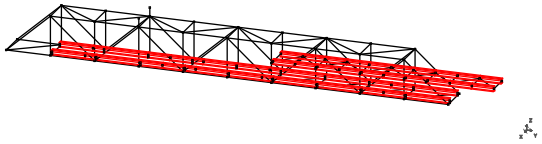

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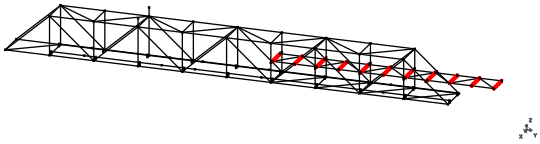

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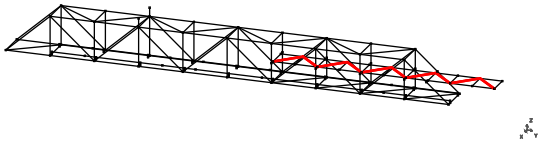


Item 018

Figure 4: Items 012-018 (Boom)

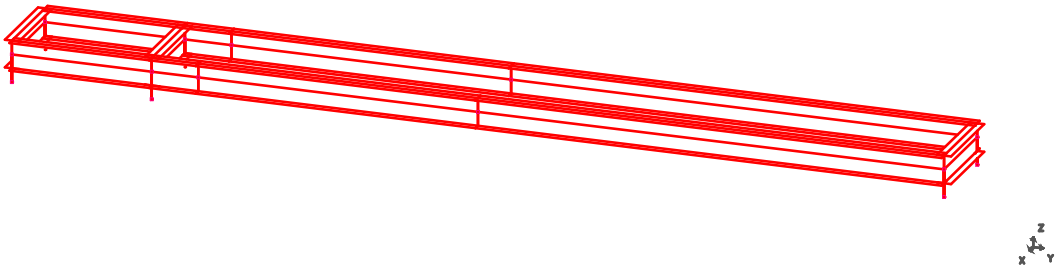


Figure 5: Items 019 (Trolley)

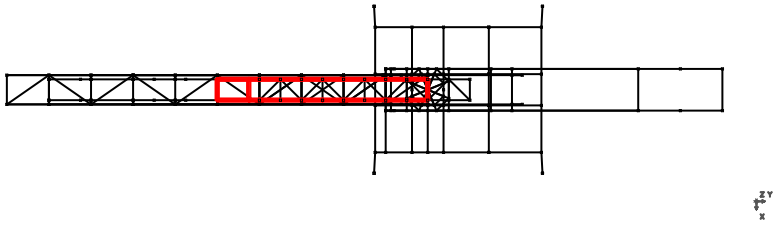
4 Working positions

During work slewing and luffing of the booms is possible. Within the boom a trolley may be moved. In KRASTA different working positions can be included in a single model. This is done by so called “situations”. The following table shows the situations used for the ship loader example.

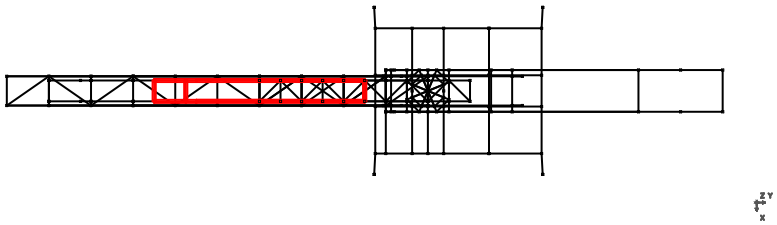
Table 3: Situation list

situation	Slewing [°]	Luffing [°]	trolley
W+000 S+000 Ka	0	0	outmost
W+000 S+000 Ki	0	0	innermost
W+000 S+000 Km	0	0	middle
W+000 S+030 Ka	30	0	outmost
W+000 S+030 Ki	30	0	innermost
W+000 S+045 Ka	45	0	outmost
W+000 S+045 Ki	45	0	innermost
W+000 S-020 Ka	-20	0	outmost
W+000 S-020 Ki	-20	0	innermost
W+010 S+000 Ka	0	10	outmost
W+010 S+000 Ki	0	10	innermost
W+010 S+030 Ka	30	10	outmost
W+010 S+030 Ki	30	10	innermost
W+010 S+045 Ka	45	10	outmost
W+010 S+045 Ki	45	10	innermost
W+010 S-020 Ka	-20	10	outmost
W+010 S-020 Ki	-20	10	innermost
W-015 S+000 Ka	0	-15	outmost
W-015 S+000 Ki	0	-15	innermost
W-015 S+030 Ka	30	-15	outmost
W-015 S+030 Ki	30	-15	innermost
W-015 S+045 Ka	45	-15	outmost
W-015 S+045 Ki	45	-15	innermost
W-015 S-020 Ka	-20	-15	outmost
W-015 S-020 Ki	-20	-15	innermost
W+025 S+090 Ki *)	90	25	innermost

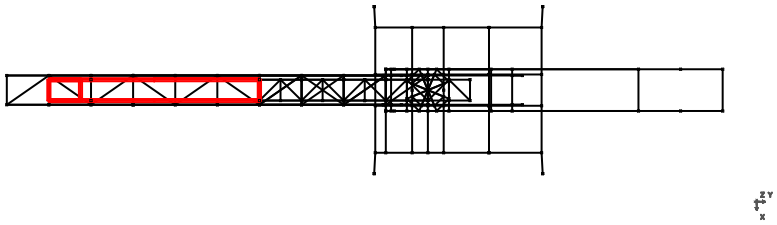
*) out of service position



trolley innermost

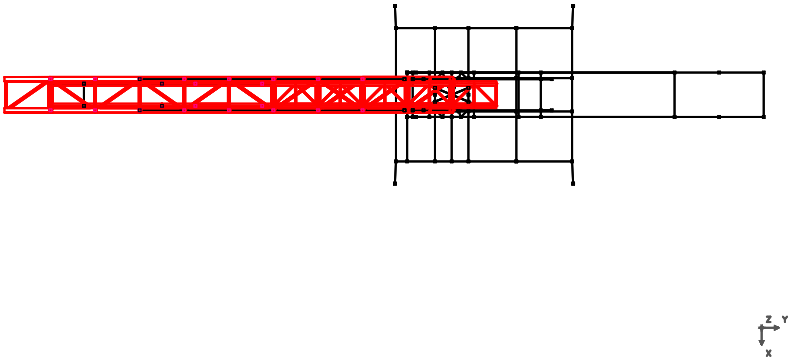


trolley middle

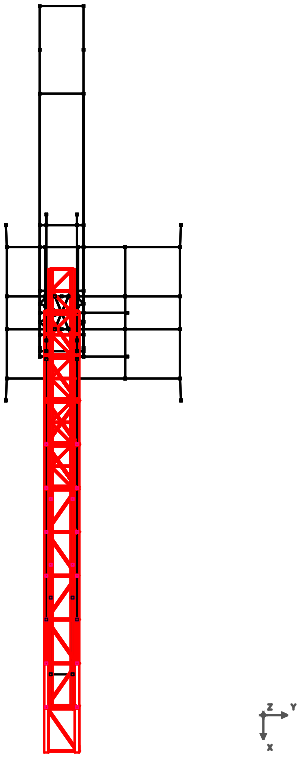


trolley outmost

Figure 6: trolley movement

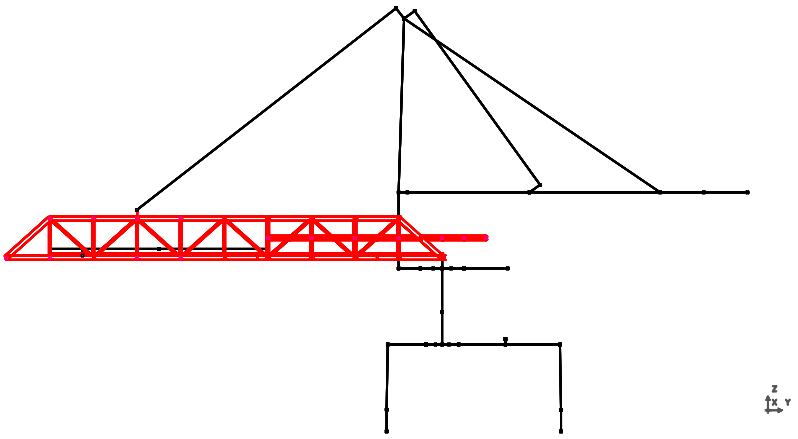


Slewing: 0 deg

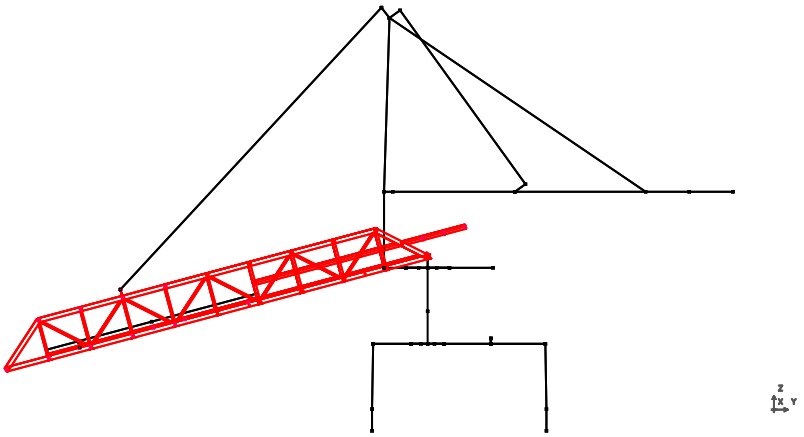


Slewing: +90 deg (out of service)

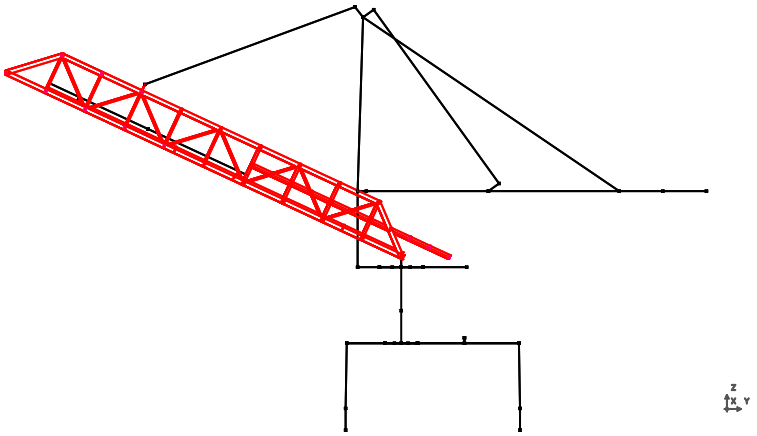
Figure 7: boom slewing



Luffing: 0 deg



Luffing: -15 deg



Luffing: +25 deg (out of service)

Figure 8: boom luffing

The situations are grouped into list to ease working with similar situations.

List { in Service }

- W+000 S+000 Ka
- W+000 S+000 Ki
- W+000 S+000 Km
- W+000 S+030 Ka
- W+000 S+030 Ki
- W+000 S+045 Ka
- W+000 S+045 Ki
- W+000 S-020 Ka
- W+000 S-020 Ki
- W+010 S+000 Ka
- W+010 S+000 Ki
- W+010 S+030 Ka
- W+010 S+030 Ki
- W+010 S+045 Ka
- W+010 S+045 Ki
- W+010 S-020 Ka
- W+010 S-020 Ki
- W-015 S+000 Ka
- W-015 S+000 Ki
- W-015 S+030 Ka
- W-015 S+030 Ki
- W-015 S+045 Ka
- W-015 S+045 Ki
- W-015 S-020 Ka
- W-015 S-020 Ki

List { out of Service }

- W+025 S+090 Ki

List { ka }

- W+000 S+000 Ka
- W+000 S+030 Ka
- W+000 S+045 Ka
- W+000 S-020 Ka
- W+010 S+000 Ka
- W+010 S+030 Ka
- W+010 S+045 Ka
- W+010 S-020 Ka
- W-015 S+000 Ka
- W-015 S+030 Ka
- W-015 S+045 Ka
- W-015 S-020 Ka

List { ki }

- W+000 S+000 Ki
- W+000 S+030 Ki
- W+000 S+045 Ki
- W+000 S-020 Ki
- W+010 S+000 Ki
- W+010 S+030 Ki
- W+010 S+045 Ki
- W+010 S-020 Ki
- W-015 S+000 Ki
- W-015 S+030 Ki
- W-015 S+045 Ki
- W-015 S-020 Ki

List { km }

- W+000 S+000 Km

5 Support conditions

All bogies are fixed in vertical and transverse rail direction. In rail direction two driven bogies are fixed. The bogies have 8 wheels. Thus, the bogies are fixed in rotational direction about the global y-axis. The bearing above the bogies is included in the model with an according beam joint.

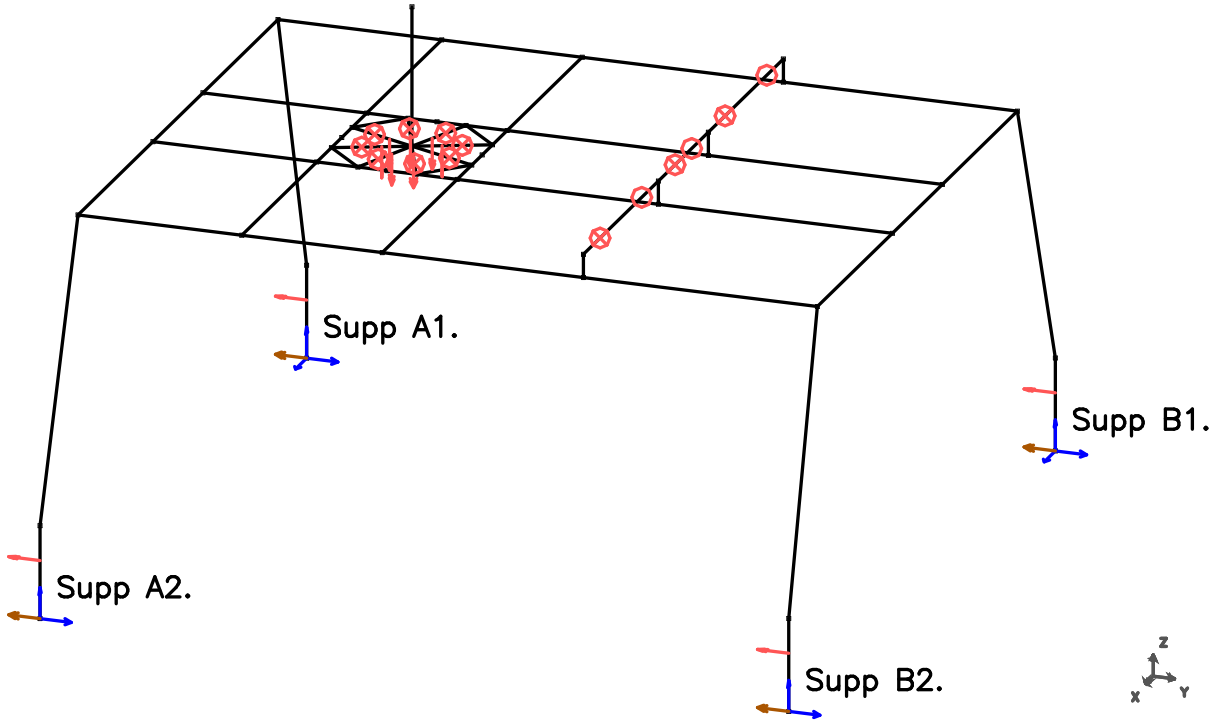


Figure 9: Support

6 Load assumptions

6.1 Deadweight

The structural mass is calculated from beam lengths, cross sections and material density for the structure included in the calculation model. These masses are increased by mass factors to account for connections and smaller parts.

Masses for machinery are taken from separate mass lists and/or drawings.

6.2 Payloads

Product throughput	1600 t/h

Product masses on conveyors are derived accordingly.

6.3 Windloads

Wind in service	20 m/s	0.25 kN/m²
Wind out of service	51,75 m/s	1.67 kN/m²

6.4 Dynamic factors and loading group

Dynamic factor on deadweight of booms:	1.1
Dynamic factor on payload on booms:	1.1
Loading group:	B4

7 Listing of masses

The masses are taken from separate mass list where available. The naming corresponds to the names of basic mass cases used in the calculation model.

Table 4: Masses of product and equipment

MB01	Product on fixed boom conveyor	1800 kg
MB01	Product on moveable boom conveyor, outmost position	1530 kg
MB01	Product on moveable boom conveyor, innermost position	90 kg
MB01	Product on moveable boom conveyor, middle position	630 kg
MB02	Fixed boom conveyor	3000 kg
MB03	Moveable boom conveyor	2550 kg
MB04	Belt head	1400 kg
MB05	Drive	1600 kg
MB06	Chute	500 kg
MB07	Charger	1200 kg
MB08	Discharge pipe	3200 kg
MB09	Snatch block	1400 kg
MB10	Trolley	3000 kg
MB11	Ballast	17000 kg
MB12	Bogies	32000 kg
MB13	Cabin	1800 kg
MB14	Winch	3000 kg
MB15	Hydraulics	2500 kg
MB16	Electric House	10000 kg
MB17	Slewing ring	5000 kg

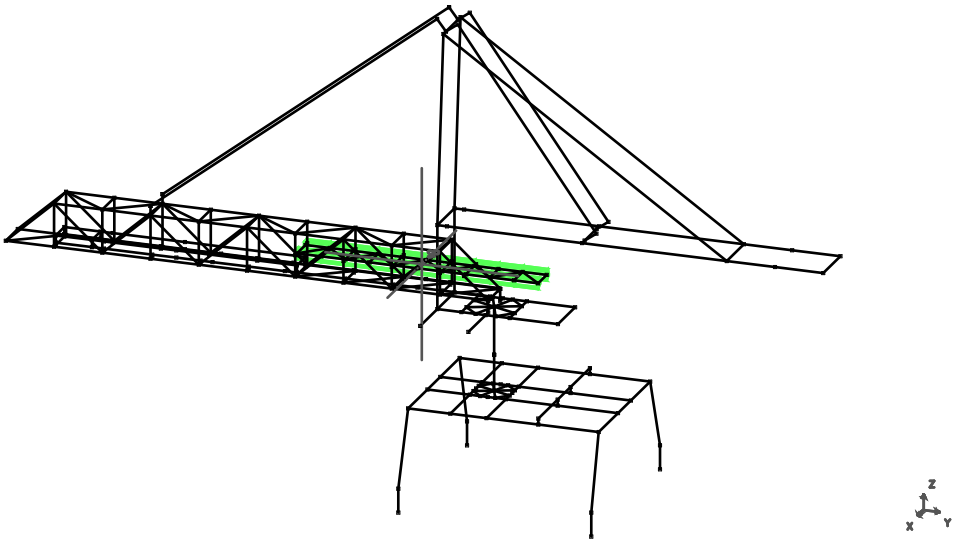
Table 5: Structural mass

SBoom	Structural mass of boom included as beams	14840 kg
SPortal	Structural mass of portal included as beams	30942 kg
STowerTop	Mass of slewing pin on top of tower	2500 kg
SUpperCrane	Structural mass of upper crane on portal included as beams	30741 kg

7.1 List of Mass cases in the beam model

7.1.1 Basic mass cases

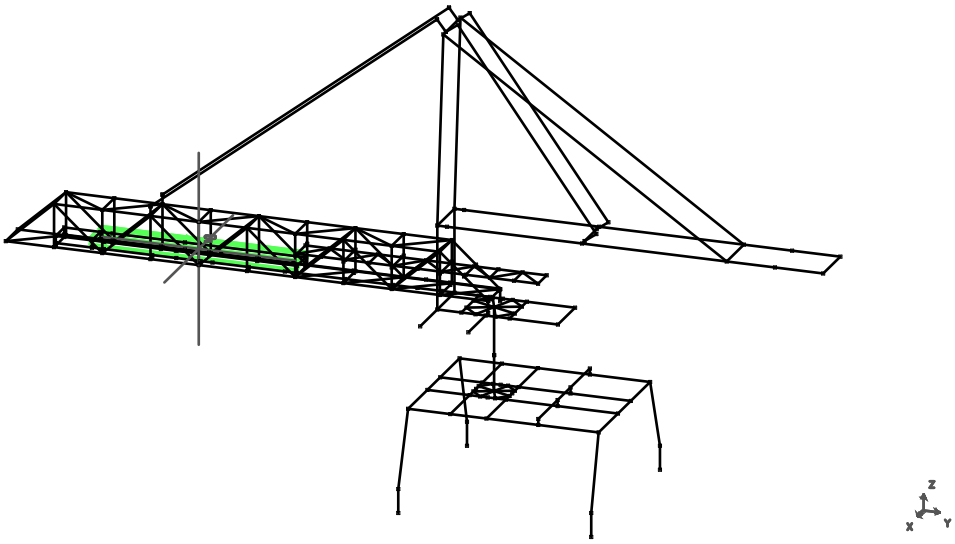
MB01 product dis



```
masses, mass case: MB01 product dis

total of node masses              :        .0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :    1800.0   [kg]
total of all masses               :    1800.0   [kg]
centre of gravity                 :      3.0   ,     -8.4   ,      8.9    [m]
```

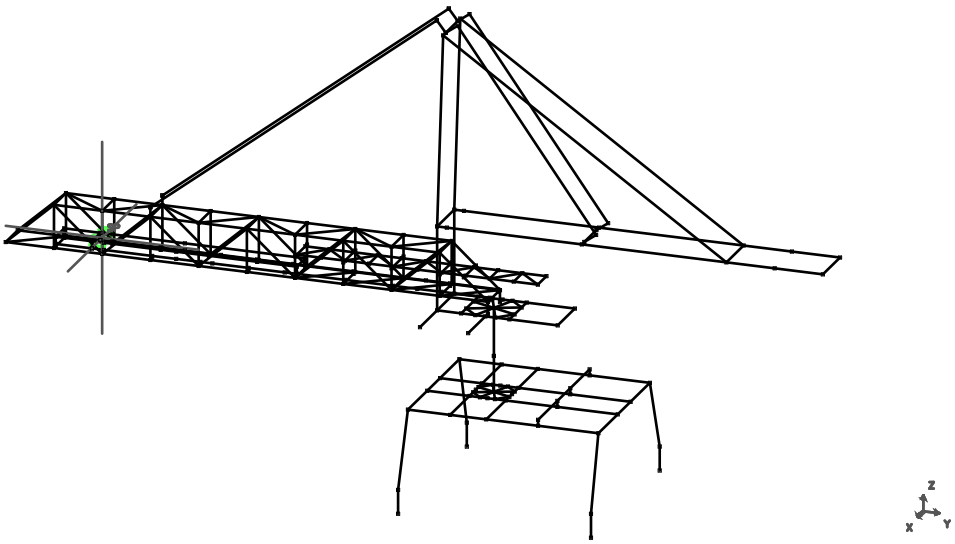
MB01 product ka



```
masses, mass case: MB01 product ka

total of node masses              :        .0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :    1530.0   [kg]
total of all masses               :    1530.0   [kg]
centre of gravity                 :      3.0001,    -17.65  ,      8.3999 [m]
```

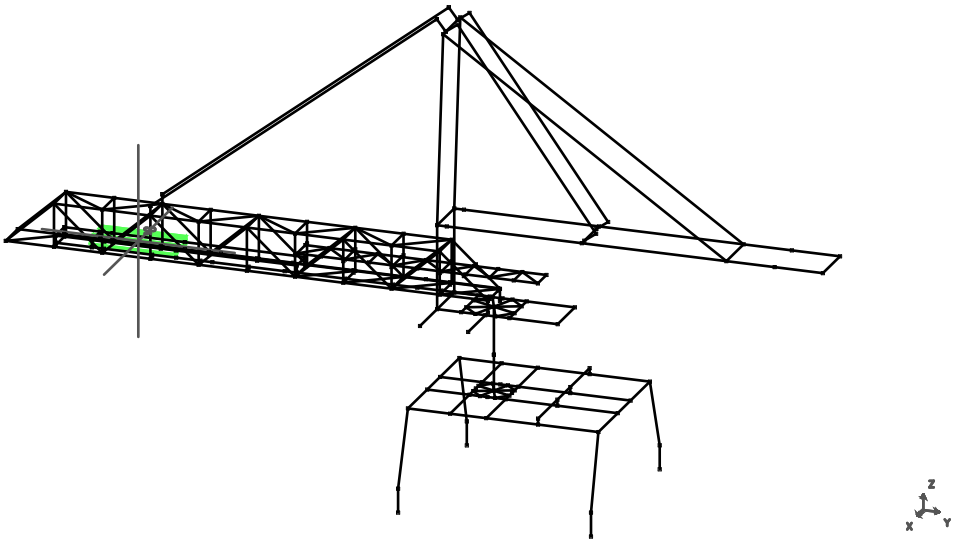
MB01 product ki



```
masses, mass case: MB01 product ki

total of node masses              :        .0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :     89.999 [kg]
total of all masses               :     89.999 [kg]
centre of gravity                 :     3.0001,    -21.65  ,      8.3999 [m]
```

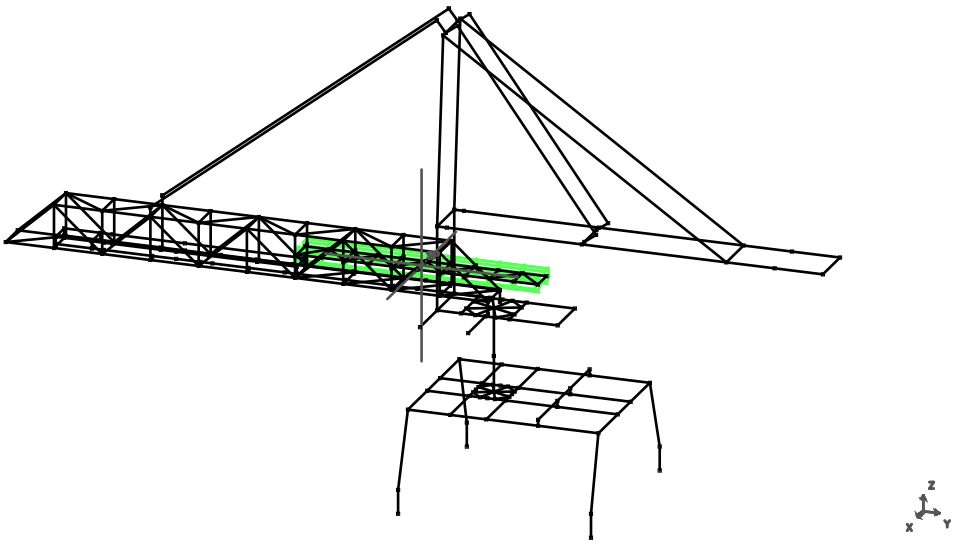
MB01 product km



```
masses, mass case: MB01 product km

total of node masses              :        .0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :    629.999 [kg]
total of all masses               :    629.999 [kg]
centre of gravity                 :     3.0001,    -20.15  ,      8.3999 [m]
```

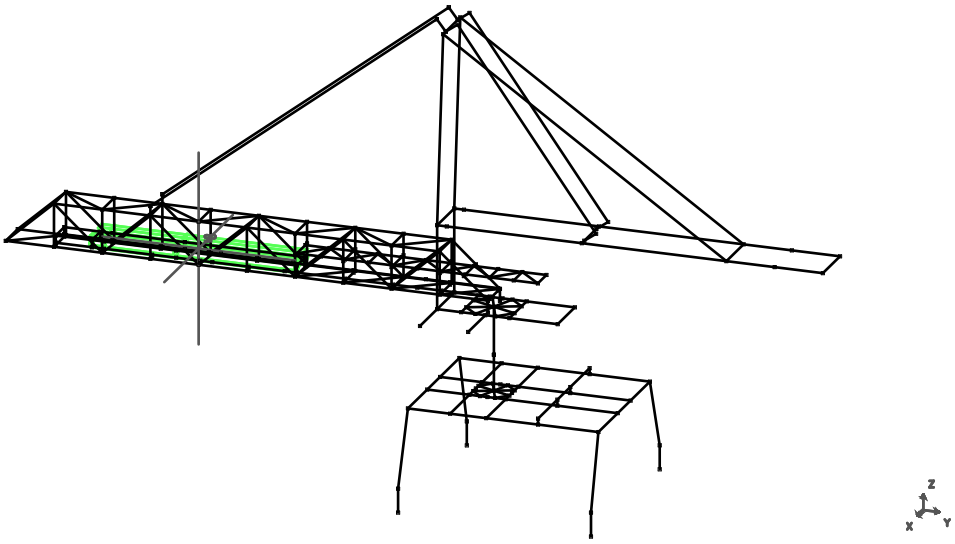
MB02 conv 1



```
masses, mass case: MB02 conv 1

total of node masses              :        .0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :    3000.0   [kg]
total of all masses               :    3000.0   [kg]
centre of gravity                 :      3.0   ,     -8.4   ,      8.9    [m]]
```

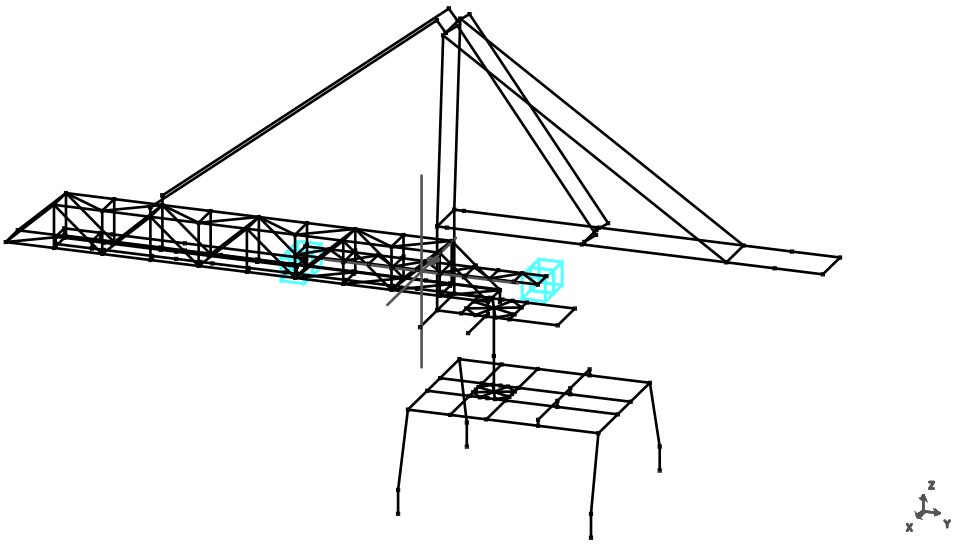
MB03 conv 2



```
masses, mass case: MB03 conv 2

total of node masses              :        .0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :    2550.0   [kg]
total of all masses               :    2550.0   [kg]
centre of gravity                 :      3.0001,    -17.65  ,      8.3999 [m]
```

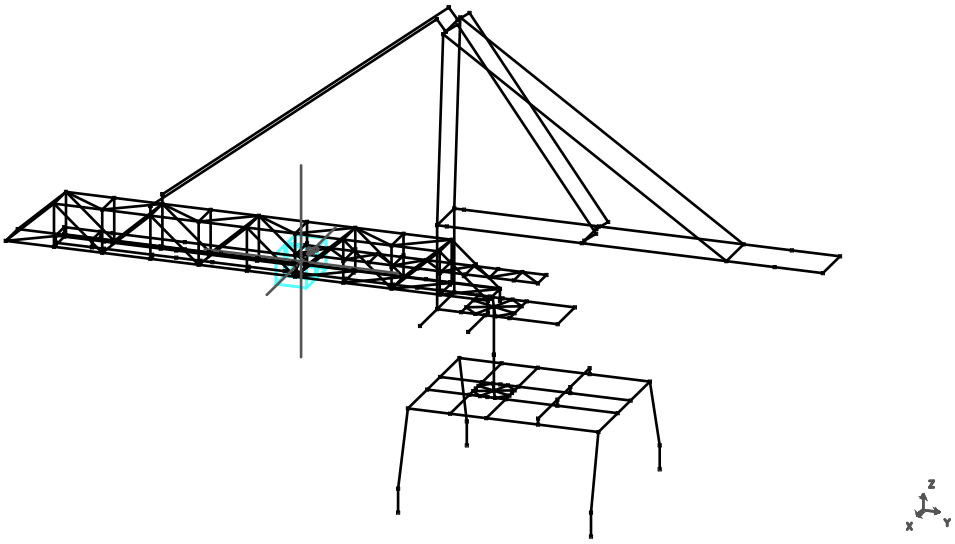
MB04 belthead



```
masses, mass case: MB04 belthead

total of node masses              :    1400.0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :        .0   [kg]
total of all masses               :    1400.0   [kg]
centre of gravity                 :      3.0   ,     -8.4   ,      8.65   [m]
```

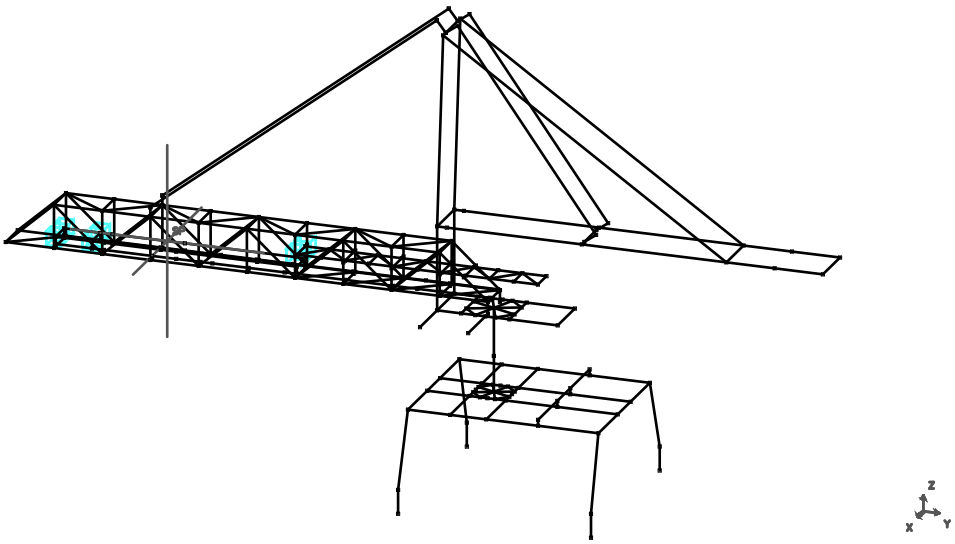
MB05 drive



```
masses, mass case: MB05 drive

total of node masses              :    1600.0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :        .0   [kg]
total of all masses               :    1600.0   [kg]
centre of gravity                 :      3.0001,    -13.4   ,      8.4    [m]
```

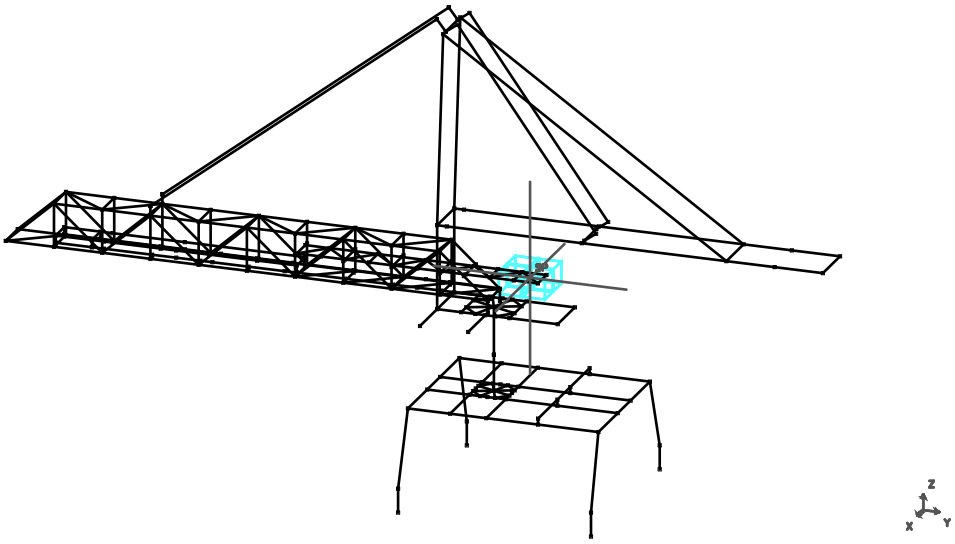
MB06 chute



```
masses, mass case: MB06 chute

total of node masses              :     500.0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :        .0   [kg]
total of all masses               :     500.0   [kg]
centre of gravity                 :      3.0001,    -18.95   ,      8.5999 [m]
```

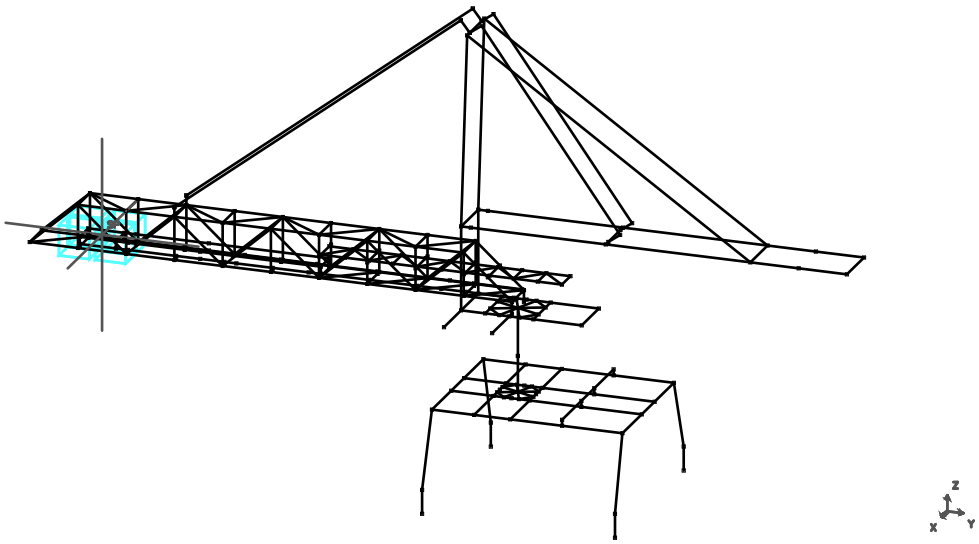
MB07 charger



```
masses, mass case: MB07 charger

total of node masses              :    1200.0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :        .0   [kg]
total of all masses               :    1200.0   [kg]
centre of gravity                 :      3.0    ,     -3.9    ,      8.9     [m]
```

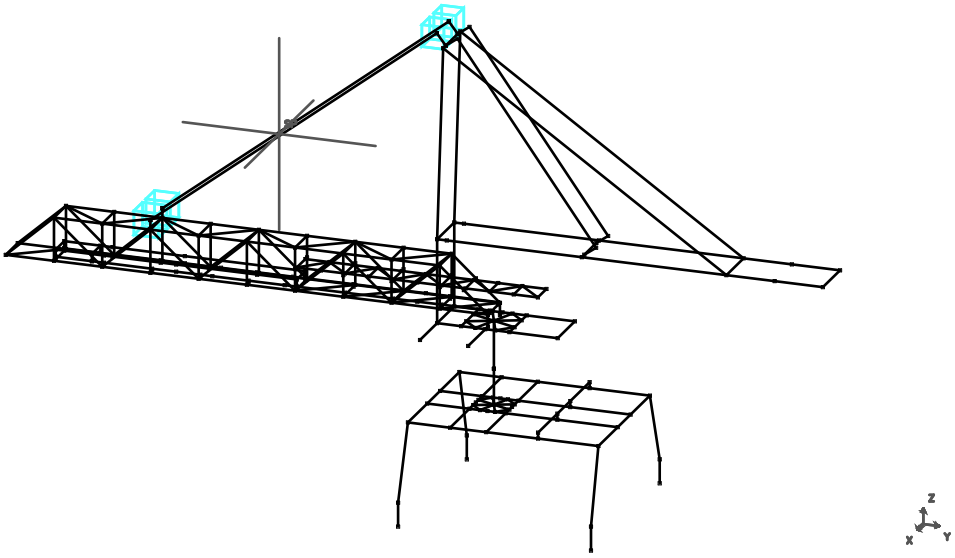
MB08 discharge p



```
masses, mass case: MB08 discharge p

total of node masses              :    3200.0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :        .0   [kg]
total of all masses               :    3200.0   [kg]
centre of gravity                 :      3.0001,    -22.65  ,      8.3999 [m]
```

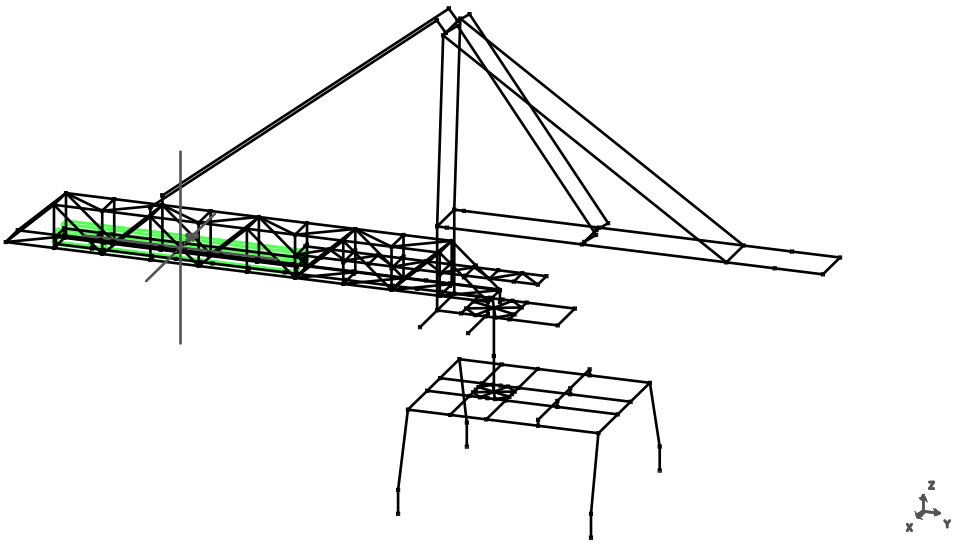
MB09 snatch bloc



```
masses, mass case: MB09 snatch bloc

total of node masses              :    1400.0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :        .0   [kg]
total of all masses               :    1400.0   [kg]
centre of gravity                 :      3.0001,    -14.3082,     14.1741 [m]
```

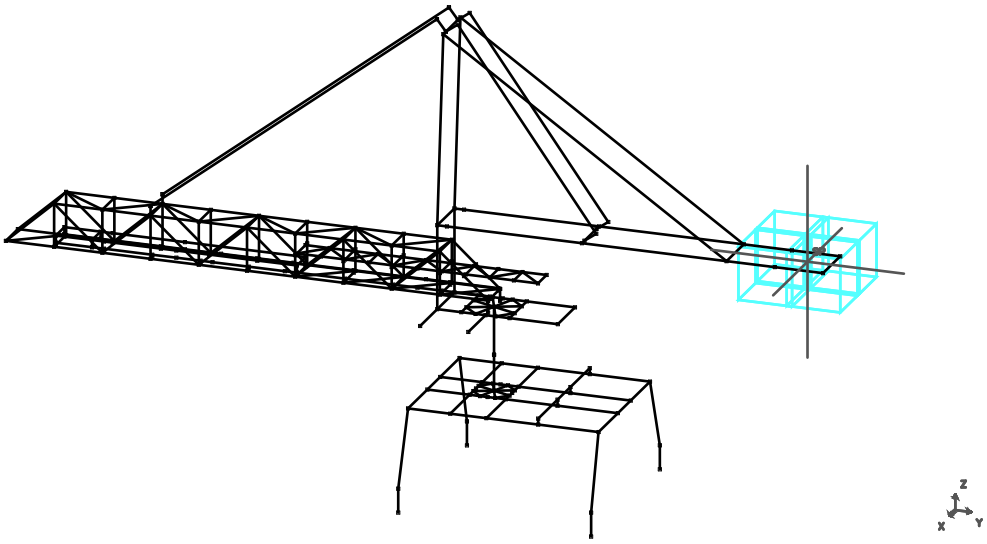
MB10 trolley



```
masses, mass case: MB10 trolley

total of node masses              :        .0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :    3000.0   [kg]
total of all masses               :    3000.0   [kg]
centre of gravity                 :      3.0001,    -18.4    ,      8.3999 [m]
```

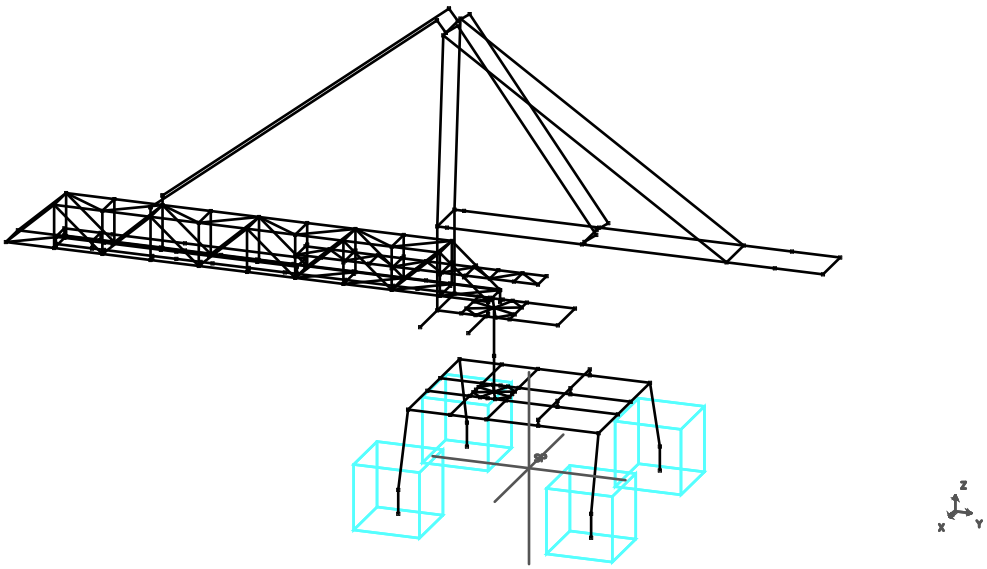
MB11 ballast



```
masses, mass case: MB11 ballast

total of node masses              :   17000.0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :        .0   [kg]
total of all masses               :   17000.0   [kg]
centre of gravity                 :      2.9999,      7.6    ,     11.0     [m]
```

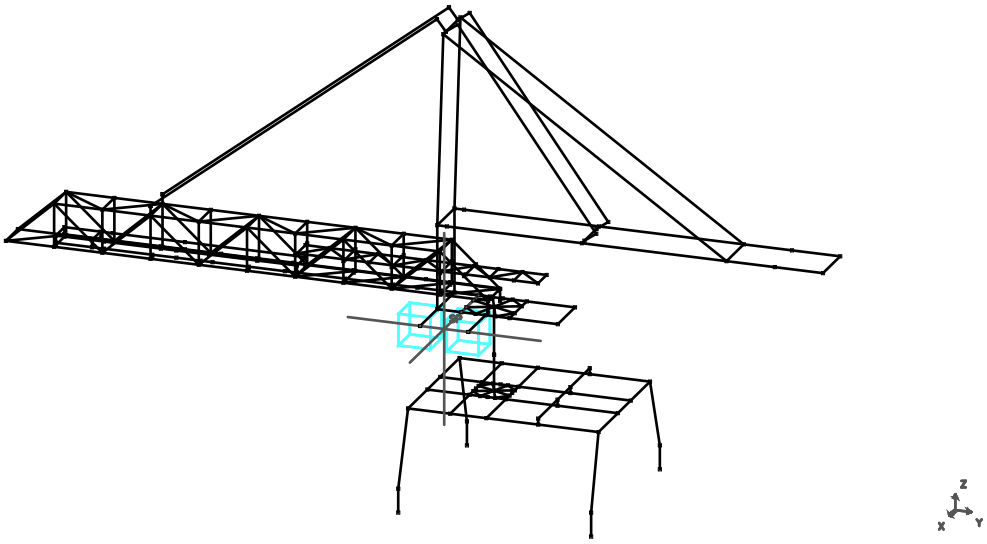
MB12 bogies



masses, mass case: MB12 bogies

total of node masses	:	32000.0	[kg]			
total of beam concentrated masses	:	.0	[kg]			
total of distributed masses	:	.0	[kg]			
total of all masses	:	32000.0	[kg]			
centre of gravity	:	3.0	,	-3.95	,	1.0 [m]

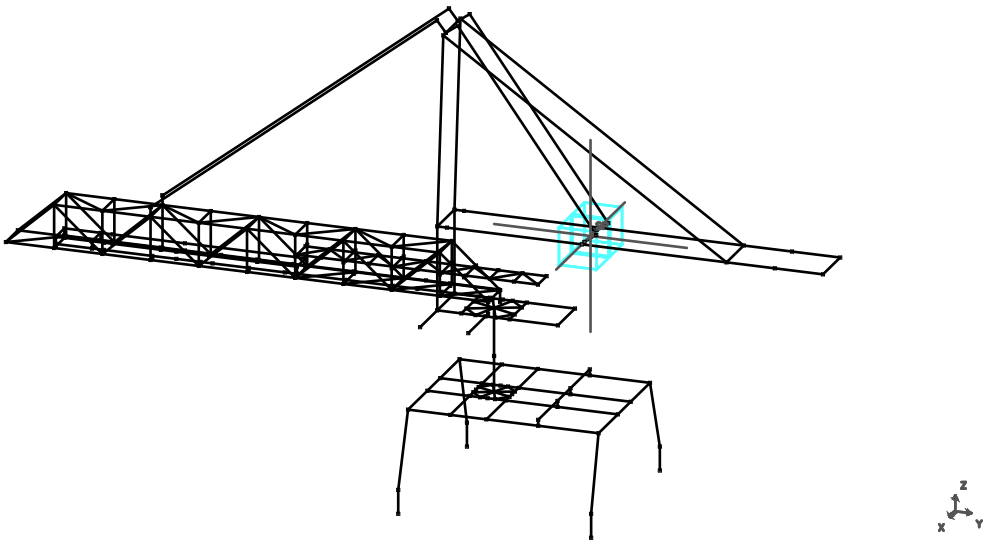
MB13 cabin



masses, mass case: MB13 cabin

total of node masses	:	1800.0	[kg]			
total of beam concentrated masses	:	.0	[kg]			
total of distributed masses	:	.0	[kg]			
total of all masses	:	1800.0	[kg]			
centre of gravity	:	6.0	,	-6.4	,	7.5 [m]

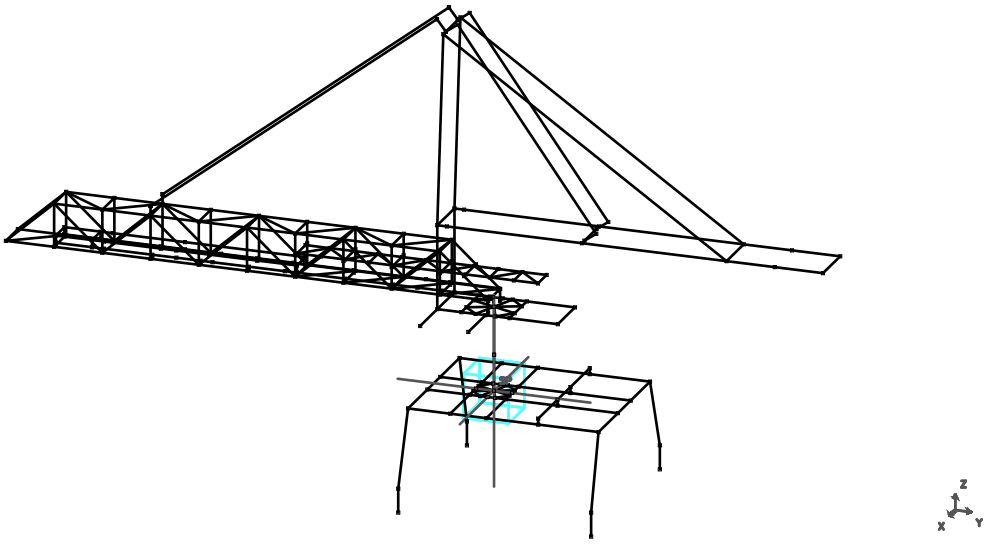
MB14 winch



```
masses, mass case: MB14 winch

total of node masses              :    3000.0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :        .0   [kg]
total of all masses               :    3000.0   [kg]
centre of gravity                 :      3.0   ,     -1.4   ,     11.0    [m]
```

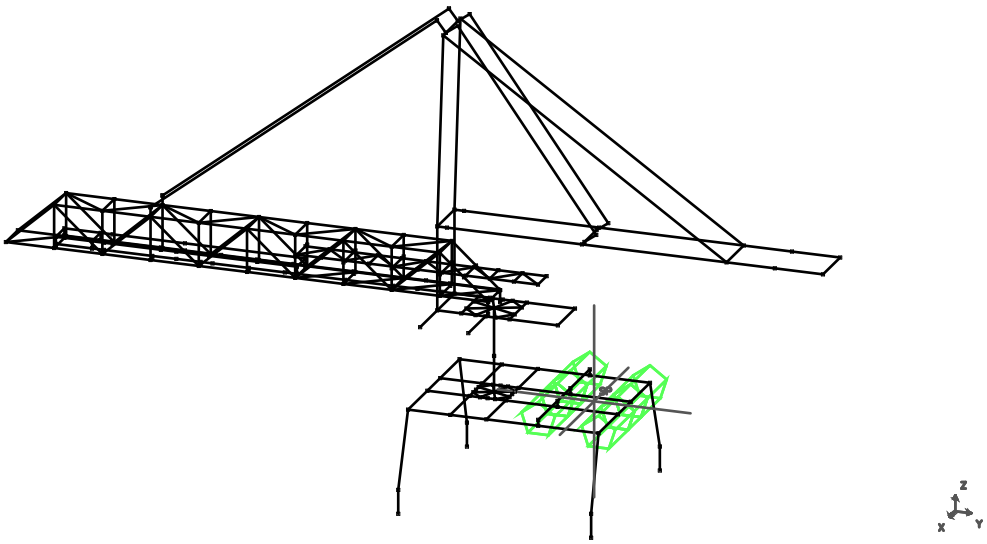
MB15 hydraulics



```
masses, mass case: MB15 hydraulics

total of node masses              :    2500.0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :        .0   [kg]
total of all masses               :    2500.0   [kg]
centre of gravity                 :      3.0   ,     -5.4   ,      4.0    [m]
```

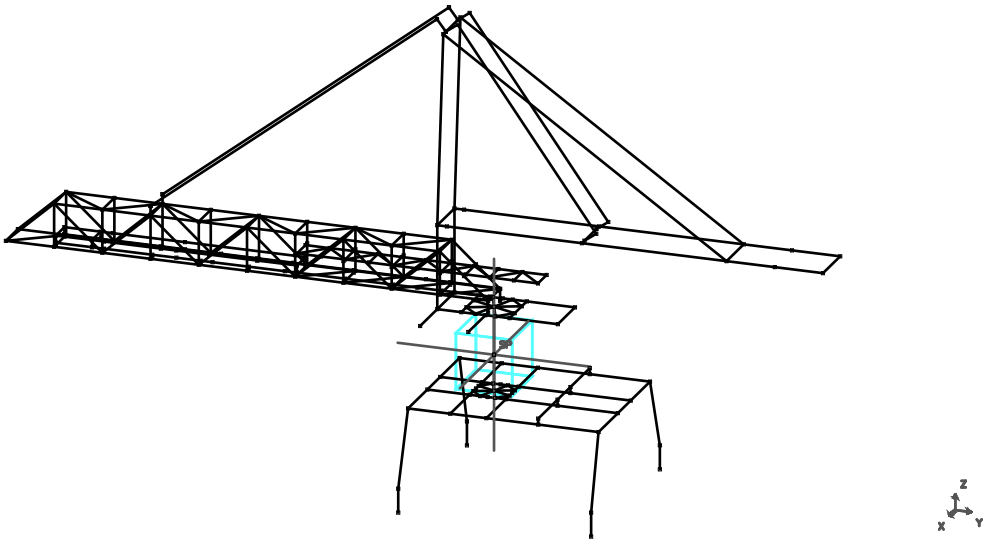
MB16 e-House



```
masses, mass case: MB16 e-House

total of node masses              :        .0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :   10000.0   [kg]
total of all masses               :   10000.0   [kg]
centre of gravity                 :      3.0   ,     -1.25   ,      4.125   [m]
```

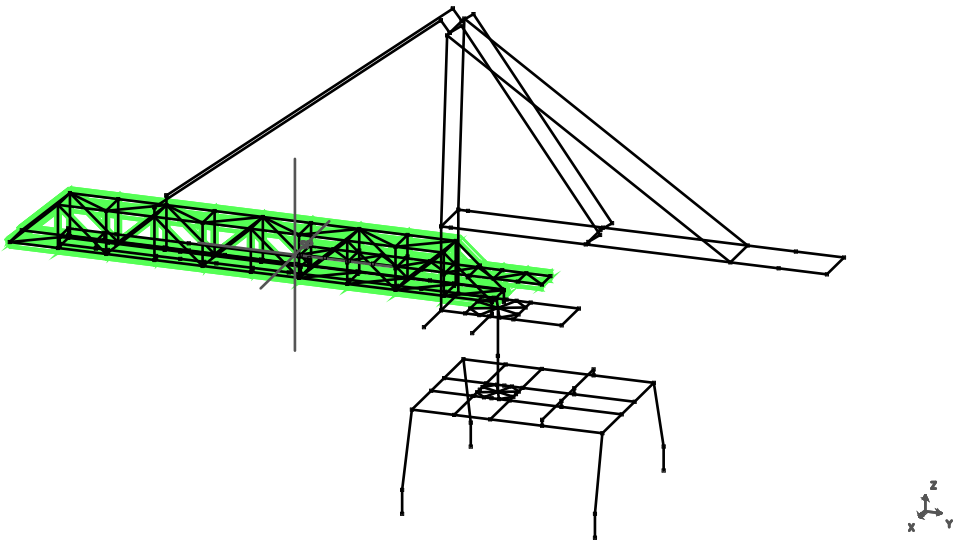
MB17 slewing rin



```
masses, mass case: MB17 slewing rin

total of node masses              :    5000.0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :        .0   [kg]
total of all masses               :    5000.0   [kg]
centre of gravity                 :      3.0   ,     -5.4    ,      5.5     [m]
```

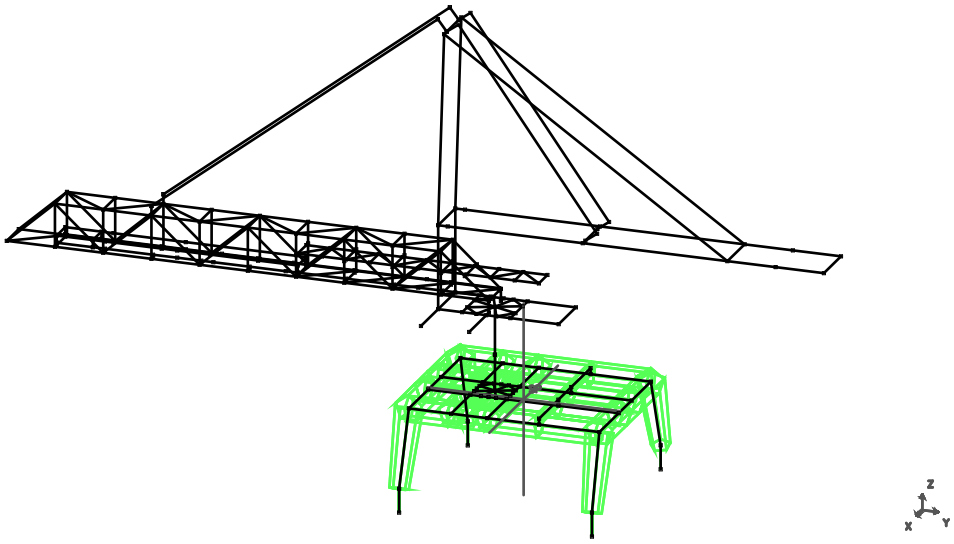
SBoom



```
masses, mass case: SBoom

total of node masses              :        .0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :   14838.464 [kg]
total of all masses               :   14838.464 [kg]
centre of gravity                 :      3.0001,    -13.8192,      8.6674 [m]
```

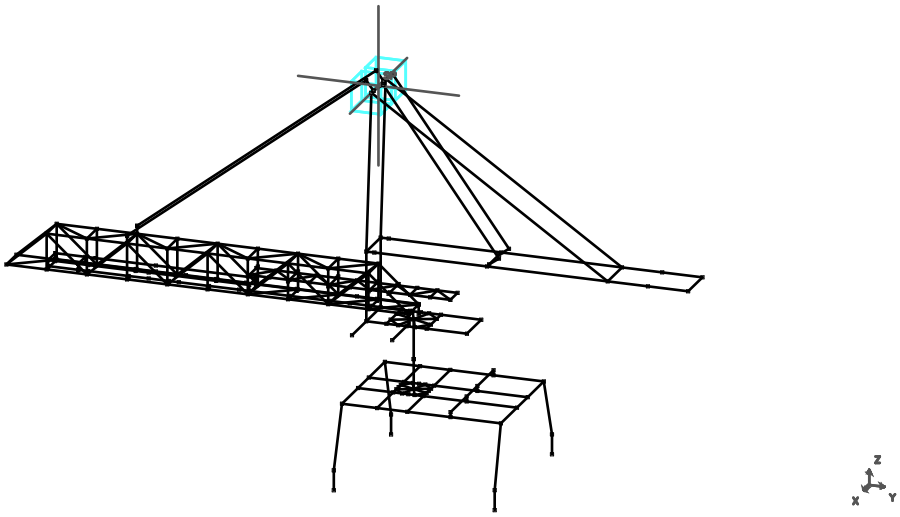
SPortal



```
masses, mass case: SPortal

total of node masses              :        .0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :   30941.904 [kg]
total of all masses               :   30941.904 [kg]
centre of gravity                 :      3.0   ,     -4.2081,      3.7941 [m]
```

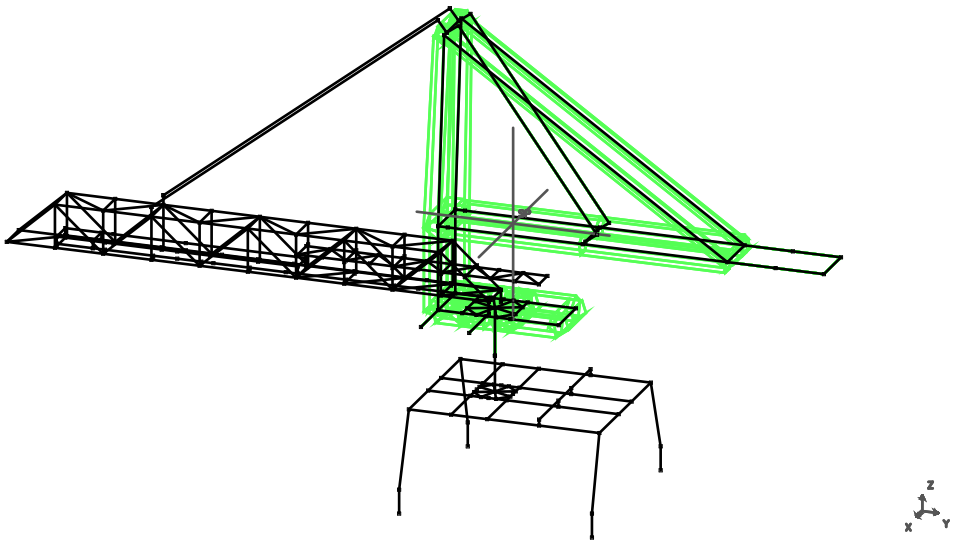
STowerTop



```
masses, mass case: STowerTop

total of node masses              :    2500.0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :        .0   [kg]
total of all masses               :    2500.0   [kg]
centre of gravity                 :      3.0   ,     -7.15  ,     19.0    [m]
```

SUpperCrane



```
masses, mass case: SUpperCrane

total of node masses              :        .0   [kg]
total of beam concentrated masses :        .0   [kg]
total of distributed masses       :   30740.833 [kg]
total of all masses               :   30740.833 [kg]
centre of gravity                 :      3.0   ,     -4.6464,     11.1005 [m]
```

7.1.2 Situation dependent mass cases

Situation dependent mass cases are used to switch the mass on the moveable conveyor according to the situation.

LL Boom Situ

- situ. list: {Ka} 1.0 x MB01 product ka
- situ. list: {Km} 1.0 x MB01 product km
- situ. list: {Ki} 1.0 x MB01 product ki
- situ. list: {out of Service} 0.0.x MB01 product ki

7.1.3 Combination mass cases

DL SL

- 1,0 x MB Boom
- 1,0 x MB Upper Crane
- 1,0 x SBoom
- 1,0 x STowerTop
- 1,0 x SUpperCrane

DL Total

- 1,0 x STB
- 1,0 x MB Boom
- 1,0 x MB Portal
- 1,0 x MB Upper Crane

LL Boom

- 1,0 x MB01 product dis
- 1,0 x LL Boom Situ

MB Boom

- 1,0 x MB04 belthead
- 1,0 x MB05 drive
- 1,0 x MB06 chute
- 1,0 x MB07 charger
- 1,0 x MB09 snatch bloc
- 1,0 x MB08 discharge p
- 1,0 x MB10 trolley

MB Portal

- 1,0 x MB12 bogies
- 1,0 x MB15 hydraulics
- 1,0 x MB16 e-House
- 1,0 x MB17 slewing rin

MB Upper Crane

- 1,0 x MB11 ballast
- 1,0 x MB14 winch
- 1,0 x MB13 cabin

STB

- 1,0 x SBoom
- 1.0 x SPortal
- 1.0 x STowerTop
- 1.0 x SUpperCrane

8 Listing of load cases

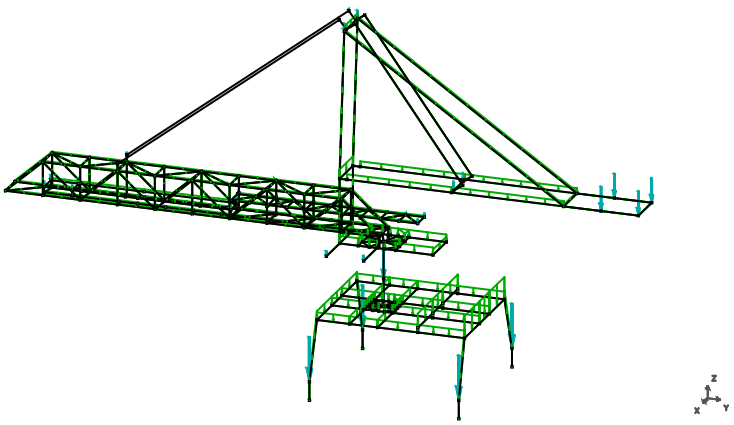
8.1 Basic load cases

Table 6: Basic load cases

DL Total	Gravity load on combination mass case “DL Total”
DR +x	Acceleration in positive x-axis direction with $a = 0.25\ m/s^2$
LL	Gravity load on combination mass case “LL Boom”
SL	Slewing around positive z-axis with $a = 0.3\ °/s^2$
W 20 m/s +x	Wind in +x direction
W 20 m/s +y	Wind in +y direction

Load cases in the following are displayed for situation “W+000 S+000 Ka and may be different for other situations.

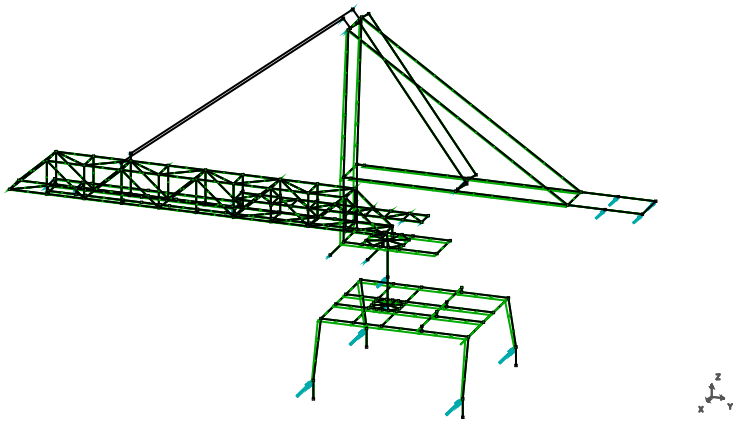
DL Total



```
loads, load case: DL Total

total of node loads        :      .0    ,      .0    ,  -717.11103 [kN]
total of beam conc. loads  :      .0    ,      .0    ,      .0     [kN]
total of distrib. loads    :      .0    ,      .0    ,  -878.20301 [kN]
total of all forces        :      .0    ,      .0    , -1595.31405 [kN]
total of node moments      :     .0     ,     .0     ,     .0      [kNm]
total of beam conc. moments:     .0     ,     .0     ,     .0      [kNm]
total of distrib. moments  :     .0     ,     .0     ,     .0      [kNm]
total of all moments       :     .0     ,     .0     ,     .0      [kNm]
reference point            :       .0   ,       .0   ,       .0   [m]
resulting moments          :  7.4258E+03,  4.8389E+03,     .0     [kNm]
point of balanced overturning moments
            at x-y plane:      3.0332,     -4.6547,       .0    [m]
```

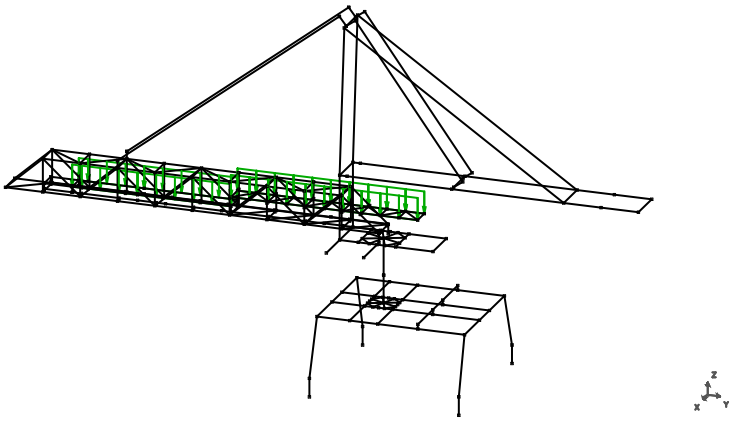
DR +x



```
loads, load case: DR +x

total of node loads        :   -18.275  ,      .0    ,      .0     [kN]
total of beam conc. loads  :      .0    ,      .0    ,      .0     [kN]
total of distrib. loads    :   -22.3803 ,      .0    ,      .0     [kN]
total of all forces        :   -40.6553 ,      .0    ,      .0     [kN]
total of node moments      :     .0     ,     .0     ,     .0      [kNm]
total of beam conc. moments:     .0     ,     .0     ,     .0      [kNm]
total of distrib. moments  :     .0     ,     .0     ,     .0      [kNm]
total of all moments       :     .0     ,     .0     ,     .0      [kNm]
reference point            :       .0   ,       .0   ,       .0    [m]
resulting moments          :     .0     , -272.862314, -189.239824 [kNm]
point of balanced overturning moments
            at y-z plane:       .0   ,     -4.6547,      6.7116 [m]
```

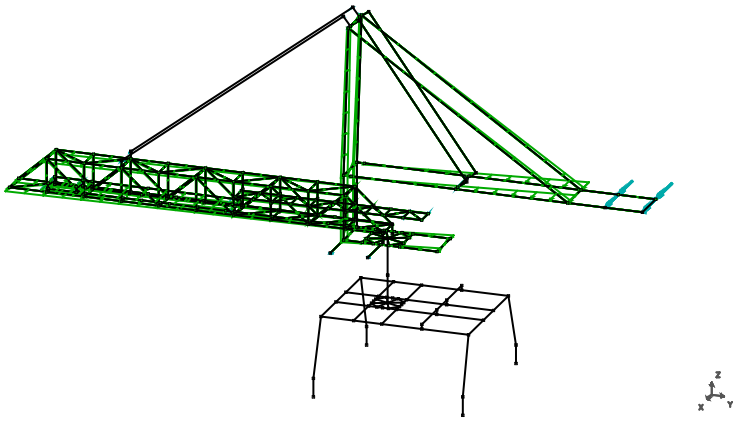
LL



```
loads, load case: LL

total of node loads        :      .0    ,      .0    ,      .0     [kN]
total of beam conc. loads  :      .0    ,      .0    ,      .0     [kN]
total of distrib. loads    :      .0    ,      .0    ,   -32.6673  [kN]
total of all forces        :      .0    ,      .0    ,   -32.6673  [kN]
total of node moments      :     .0     ,     .0     ,     .0      [kNm]
total of beam conc. moments:     .0     ,     .0     ,     .0      [kNm]
total of distrib. moments  :     .0     ,     .0     ,     .0      [kNm]
total of all moments       :     .0     ,     .0     ,     .0      [kNm]
reference point            :       .0   ,       .0   ,       .0   [m]
resulting moments          :  413.241454,   98.003804,     .0     [kNm]
point of balanced overturning moments
            at x-y plane:      3.0001,    -12.65  ,       .0    [m]
```

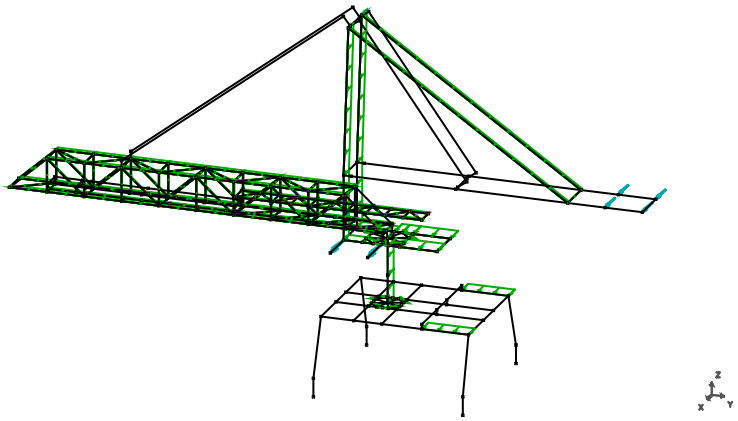
SL



```
loads, load case: SL

total of node loads          :      .71827,     -.02827,      .0      [kN]
total of beam conc. loads    :      .0    ,      .0    ,      .0      [kN]
total of distrib. loads      :     -.73703, -6.6367E-06,      .0      [kN]
total of all forces          :     -.01876,     -.02828,      .0      [kN]
total of node moments        :     .0     ,     .0     ,     .0       [kNm]
total of beam conc. moments:     .0     ,     .0     ,     .0       [kNm]
total of distrib. moments    :     .0     ,     .0     ,     .0       [kNm]
total of all moments         :     .0     ,     .0     ,     .0       [kNm]
reference point              :       .0   ,       .0   ,       .0    [m]
resulting moments            :     .212096,    2.615339,  -36.07816  [kNm]
point of balanced overturning moments
            at y-z plane:       .0   ,  -1922.8306,   -139.3877 [m]
            at x-z plane:   1275.7544,       .0   ,      7.4999 [m]
```

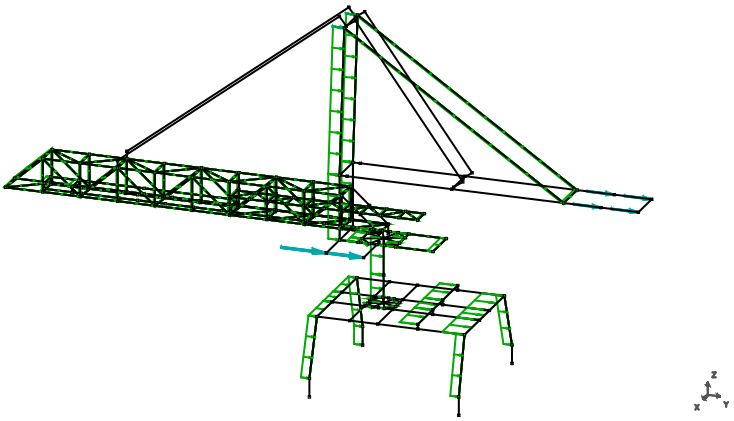
W 20 m/s +x



```
loads, load case: W 20 m/s +x

total of node loads        :     6.15    ,      .0    ,      .0     [kN]
total of beam conc. loads  :      .0     ,      .0    ,      .0     [kN]
total of distrib. loads    :    44.03194,      .22955, -1.3803E-06 [kN]
total of all forces        :    50.18194,      .22955, -1.3803E-06 [kN]
total of node moments      :     .0     ,     .0     ,     .0      [kNm]
total of beam conc. moments:     .0     ,     .0     ,     .0      [kNm]
total of distrib. moments  :     .0     ,     .0     ,     .0      [kNm]
total of all moments       :     .0     ,     .0     ,     .0      [kNm]
reference point            :       .0   ,       .0   ,       .0    [m]
resulting moments          :   -1.836596,  482.911608,  433.078176 [kNm]
point of balanced overturning moments
            at y-z plane:       .0   ,     -8.6302,      9.6232 [m]
            at x-z plane:   1886.6369,       .0   ,      8.0008 [m]
```

W 20 m/s +y



```
loads, load case: W 20 m/s +y

total of node loads        :      .0    ,     6.15   ,      .0     [kN]
total of beam conc. loads  :      .0    ,      .0    ,      .0     [kN]
total of distrib. loads    :      .22957,    35.0367 ,      .85499 [kN]
total of all forces        :      .22957,    41.1867 ,      .85499 [kN]
total of node moments      :     .0     ,     .0     ,     .0      [kNm]
total of beam conc. moments:     .0     ,     .0     ,     .0      [kNm]
total of distrib. moments  :     .0     ,     .0     ,     .0      [kNm]
total of all moments       :     .0     ,     .0     ,     .0      [kNm]
reference point            :       .0   ,       .0   ,       .0    [m]
resulting moments          : -328.584552,    -.728203,  132.411063 [kNm]
point of balanced overturning moments
            at y-z plane:       .0   ,   -576.7766,     -3.172  [m]
            at x-z plane:      3.2149,       .0   ,      7.9779 [m]
            at x-y plane:       .8517,   -384.3146,       .0    [m]
```

8.2 Combination load cases

W 51,75m/s +x

6.695 x W 20 m/s +x

W 51,75m/s +y

6.695 x W 20 m/s +y

8.3 Logic load cases

Table 7: logic type

Exactly one (or-always)	exactly one of the following load cases acts at a time
One or none (or-eventually)	one or none of the following load cases acts at a time
All (and-always)	all of the following load cases act concurrently

8.3.1 Load cases for combination

This load cases combine BLC, CLC, and LLC load cases to trim down the pattern for evaluation.

LL Boom 0.1 +/-

Logic type: exactly one

- ±0.1 x LL

LL Boom 0.9/1.1.

Logic type: all

- 1.0 x LL
- 1.0 x LL Boom 0.1 +/-

W aB Logic

Logic type: exactly one

- ±1.0 x W 51,75m/s +x
- ±1.0 x W 51,75m/s +y

W iB Logic

Logic type: exactly one

- ±1.0 x W 20 m/s +x
- ±1.0 x W 20 m/s +y

8.3.2 Load cases for evaluation

H1.
Logic type: all

- 1.0 x DL Total
- 1.0 x LL Boom 0.9/1.1.
- ±1.0 x SL

H2.
Logic type: all

- 1.1 x DL Total
- 0.1 x LL
- ±1.0 x DR +x

HS1.
Logic type: all

- 1.0 x DL Total
- 1.0 x W aB Logic

HZ1.
Logic type: all

- 1.0 x H1.
- 1.0 x W iB Logic

HZ2.
Logic type: all

- 1.0 x H2.
- 1.0 x W iB Logic

in Service
Logic type: exactly one

- 1.5 x H1.
- 1.33 x HZ1.

out of Service
Logic type: exactly one

- 1.5 x H2.
- 1.33 x HZ2.
- 1.21 x HS1.

9 Evaluation pattern

The following combinations of Load case and Situation are used too proof the structure.

_Strength

Situation list	Load *case*
{in Service}	in Service
{out of service}	out of Service

_Fatigue

Situation list	Load case
{in Service}	H1.
{out of service}	H2.

10 Results and proofs

10.1 Permissible stresses

Permissible stresses according to [S1]:

St 37 (S235)

H :	perm. σ_V = 16 kN/cm^2	perm. σ_D = 14 kN/cm^2	perm. τ = 9.2 kN/cm^2
HZ:	perm. σ_V = 18 kN/cm^2	perm. σ_D = 16 kN/cm^2	perm. τ = 10.4 kN/cm^2
HS:	perm. σ_V = 19.8 kN/cm^2	perm. σ_D = 17.6 kN/cm^2	perm. τ = 11.4 kN/cm^2

St 52 (S355)

H :	perm. σ_V = 24 kN/cm^2	perm. σ_D = 21 kN/cm^2	perm. τ = 13.8 kN/cm^2
HZ:	perm. σ_V = 27 kN/cm^2	perm. σ_D = 24 kN/cm^2	perm. τ = 15.6 kN/cm^2
HS:	perm. σ_V = 30 kN/cm^2	perm. σ_D = 26.6 kN/cm^2	perm. τ = 17.3 kN/cm^2

The safety factors for loadcases H (1.5), HZ (1.33) and HS (1.21) are already incorporated in the load case pattern. Thus, the permissible stress for the model results are as follows:

St 37 (S235)

H/HZ/HS: perm. σ_V = 24 kN/cm^2 perm. τ = 13.8 kN/cm^2

St 52 (S355)

H/HZ/HS: perm. σ_V = 36 kN/cm^2 perm. τ = 20.8 kN/cm^2

10.2 Proof of stress

Part	**items**	**combined stress [kN/cm²]**	**utilization**
Boom	012-018	17.2	0.73
Portal (S235)	001-005	17.1	0.73
Trolley	019	13.8	0.59
Upper Crane	006-011	24.9	1.06

A more detailed output of stresses is available in the appendix.

10.3 Proof of fatigue

The proof of fatigue is done according to [1] for notch case K4. The loading group is B4.

Part	items	utilization
Boom	012-018	0.51
Portal	001-005	0.57
Trolley	019	0.32
Upper Crane	006-011	1.08

A more detailed output of fatigue results is available in the appendix.

10.4 Rope load

	min	*max*
In Service H	119.15 kN	144.87 kN
In Service HZ	106.42 kN	160.63 kN
Out of Service	24.31 kN	236.2 kN

A more detailed output of rope loads is available in the appendix.

10.5 Loads on slewing ring

Fx: Vertical load
Qres: Resulting horizontal load
Mx: Moment at drive/break
Mres: Resulting tilting moment

In service situation "W+000 S+000 Ka":

Loadcase	*Fx / kN*	*Qres / kN*	*Mx / kNcm*	*Mres / kNcm*
DL Total	-806.18	0.0	0.0	6358.55
LL	-32.67	0.0	0.0	23683.8
SL	0.0	0.04	-3589.2	271.91
W 20 m/s +x iB	0,0	46.7	17152.27	21162.35
W 20 m/s +y iB	0,85	25.69	881.13	12618.27

Out of service situation "oS":

Loadcase	*Fx / kN*	*Qres / kN*	*Mx / kNcm*	*Mres / kNcm*
DL total	-806.18	0.0	0.0	89596.0
LL	-17.66	0.0	0.0	4129.41
DR +x	0.0	20.54	135.01	12166.23
W 51,75m/s +x	-48.8	187.44	-5742.23	144093.71
W 51,75m/s +y	-0.65	332.72	106207.51	208625.26