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i Stavanger

DET TEKNISK-NATURVITENSKAPELIGE FAKULTET

MASTEROPPGAVE

Studieprogram/spesialisering: Konstruksjoner og materialer/Offshore konstruksjoner	Vår semesteret, 2011 Åpen
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Fagansvarlig: Rolf A. Jakobsen Veileder(e): Rolf A. Jakobsen	
Tittel på masteroppgaven: Struktur analyse av offshore modul Engelsk tittel: Structural analysis of offshore module	
Studiepoeng: 30p	
Emneord: Offshore module Bridge landing Structural analysis StaadPro analysis	Sidetall: 95 + vedlegg/annet: 23/CD Stavanger, 15/6/2011

1 SUMMARY

This thesis is the final part of the Master's program in offshore constructions at the University of Stavanger, spring 2011.

The thesis will contain analyses of an existing platform consisting of five decks, including a cellar deck. The platform has already been completed, and the objective of the thesis is to look into if there are alternative actions in order to suggest a better suited placement of the platforms bridge landing. The platform will be exposed to a set of defined loads: Environmental loads, dead loads and live loads. With the new placement of the bridge landing, the utilization of the girders will be checked. In order to prove the improvements, selected elements of the structure will be controlled.

StaadPro 2007 is used for modeling and conducting analyses of the structure. The structure is checked for ultimate- and serviceability limit states according to the requirements of the NORSOK standards.

The conclusion shows that another location for the bridge landing can be considered, depending on the assumptions made.

I would like to thank a few people that made it possible to complete this thesis:

- Rolf Jakobsen, supervisor at UiS for all the help along the way.
- Pål Berg, divisional manager at Aibel for borrowing the drawings for the platform.

CONTENT

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2 INTRODUCTION

The platform is an existing platform with five decks. It's located on the Draupner field together with another platform, connected with a bridge. For the purpose of this thesis, it is assumed that the other platform on the Draupner field has not been built. Therefore, the location of the other platform has not been taken account for, in search of finding a new placement for the bridge landing. The load on the bridge landing is an example of a bridge originally used in between the platforms Ekofisk K and Ekofisk B on the Ekofisk field.

The purpose of this thesis is to compare the original placement of the bridge landing with a new location, and come with a conclusion of which solution is the best.

When modeling the platform in StaadPro, there is created two models of the platform for each location. One model that contain, and one model that don't contain the bridge landing. A separate analysis is done for each models, and for the model with the bridge landing attached, the bridge landing is checked for with, and without the bridge attached.

A section of the platform is defined and the bridge landings surrounding beam elements will be checked in this section. Nodal displacement of the nodes surrounding the bridge landing will be checked to see if they are within the requirements set by the standard. A change of nodal displacement from the installation of the bridge landing will also be presented for each of the locations.

2.1.The Draupner E platform

The Draupner E platform is located in the North Sea at block 16/11. The operator of the field is Gassco AS. The Draupner E is the newest platform of the two, and it's installed as a part of the Europipe I pipeline that is a natural gas pipeline from Norway to continental Europe.

Figure 2.1 - Draupner E platform to the right.

2.2.Abbreviations

CD	Cellar deck
LAY	Laydown area
LC	Load case
LMD	Lower main deck
MD	Mezzane deck
NW	Wind from North West
SE	Wind from South East
SLS	Serviceability limit state

STOR	Storage area
SW	Wind from South West
ULS	Ultimate limit state
UMD	Upper main deck
VIV	Vortex induced vibrations
WALK	Walkway area
WD	Weather deck

2.3.Tables

2.4.Figures

3 STAADPRO 2007

The analysis software used for this master thesis is STAAD Pro 2007. STAAD Pro is one of the leading software for structural analysis and it includes a big number of international standards. STAAD Pro has a very flexible working environment and its easy user interface makes it a perfect tool for the problem presented in this thesis.

3.1.Coordinate system

The following axis system is used for the thesis:

X-direction is pointing to the east

Y-direction is pointing upwards

Z-direction is pointing to the north

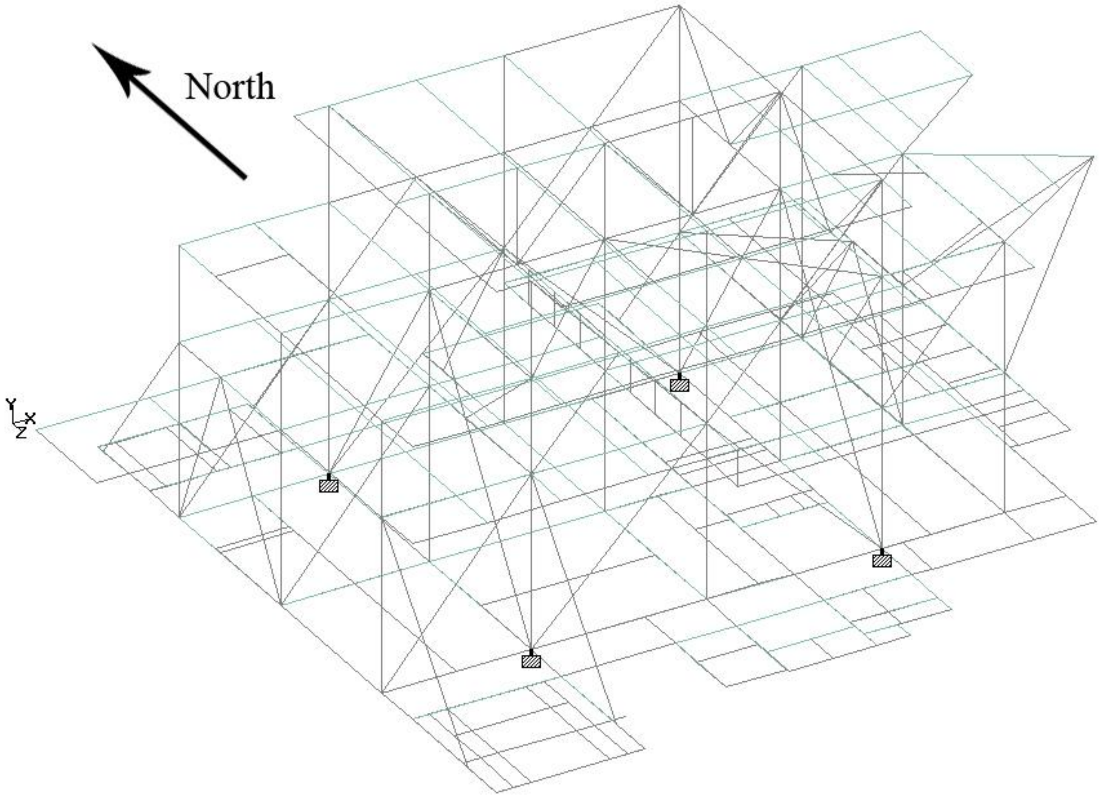


Figure 3.4 - The axis system.

3.1.Units

The following units are used StaadPro:

Length:	Millimeter, mm
Force:	Kilo Newton, kN
Force per length:	Kilo Newton per millimeter, kN/mm

In the calculation for the different loads, the unit used for force per length is kN/m. This is done to make the results more presentable. Before implementing the results in StaadPro, the results are divided with 1000, so the unit matches with the units used in StaadPro.

4 STRUCTURAL INFORMATION

4.1.Geometry

The platform consists of five decks: Cellar deck, lower main deck, upper main deck, mezzane deck and weather deck. The total height of the structure is 21m and the heights between each deck are represented in figure 4.1.

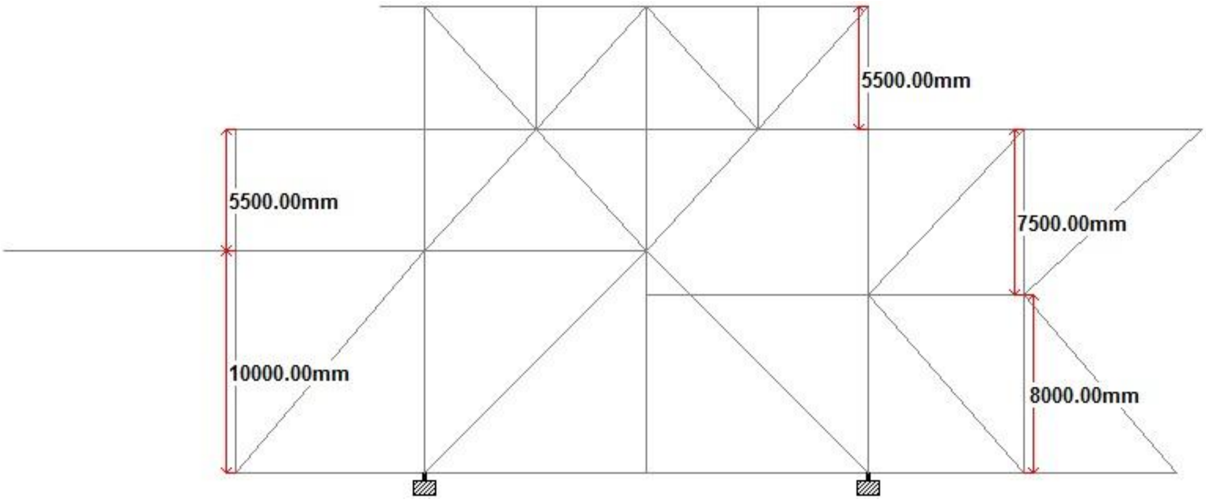


Figure 4.1 - Heights between the decks.

4.2.Nodes and beam elements

The platform consists of 579 beam elements and 303 nodes. A section of the platform is defined (See figure 4.3.1), and the beams that are interesting for the analysis are renumbered. A total of 72 beams are numbered where the first of the 72 starts with 1001 (See figure 4.3.2).

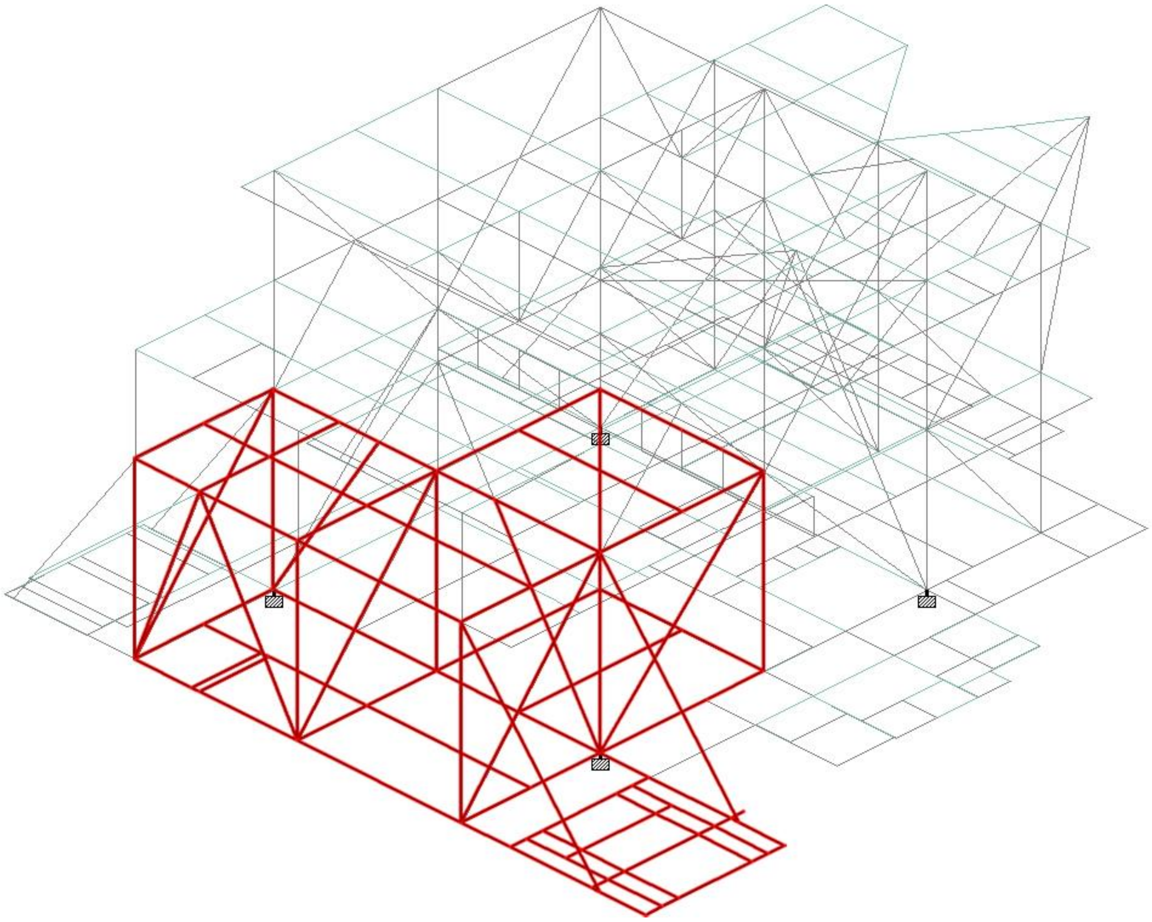


Figure 4.2.1 - Section of the platform.

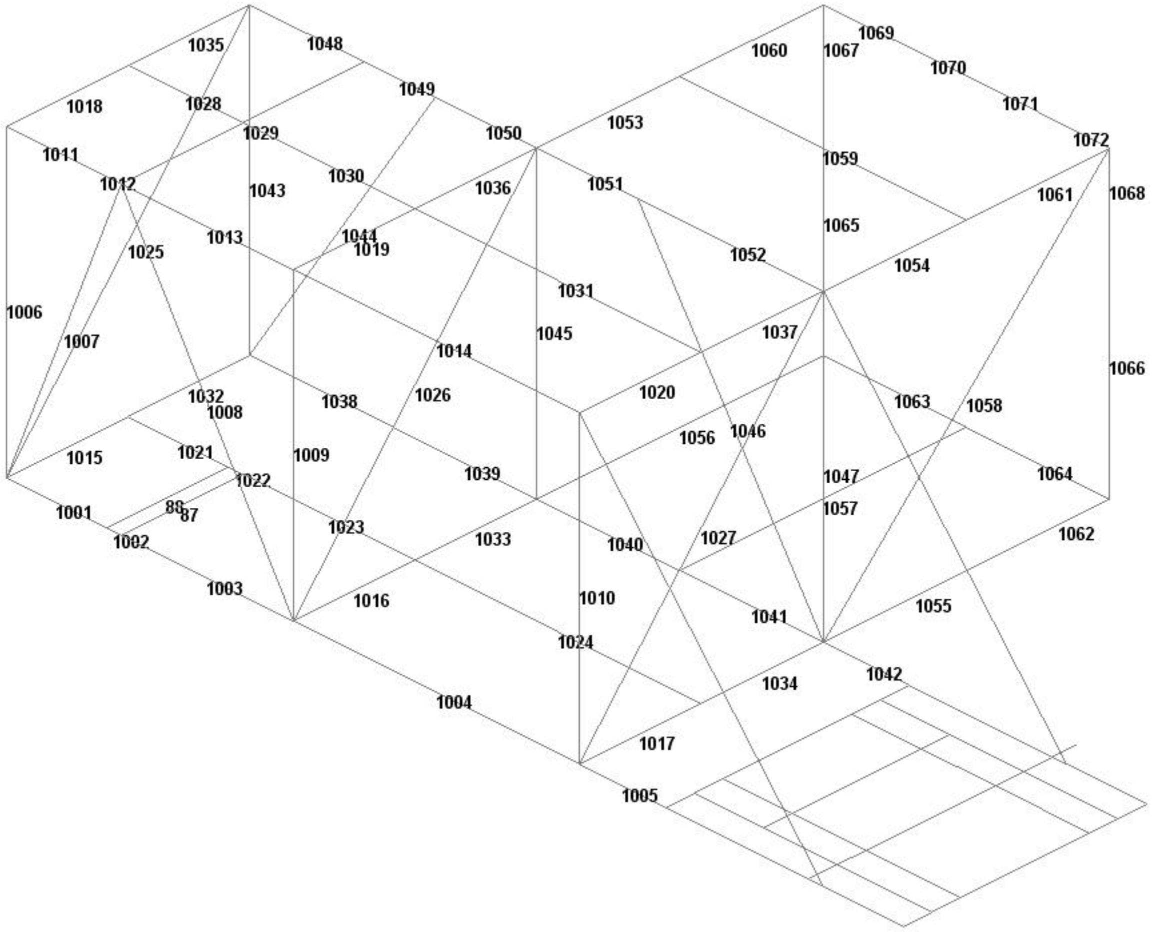


Figure 4.2.2 - Renumbered beam elements.

4.3.Supports

The platform consists of four supports and they are all fixed (See figure 4.3). This means that the support takes up all force and moment in all directions. There will be no displacement in the supports.

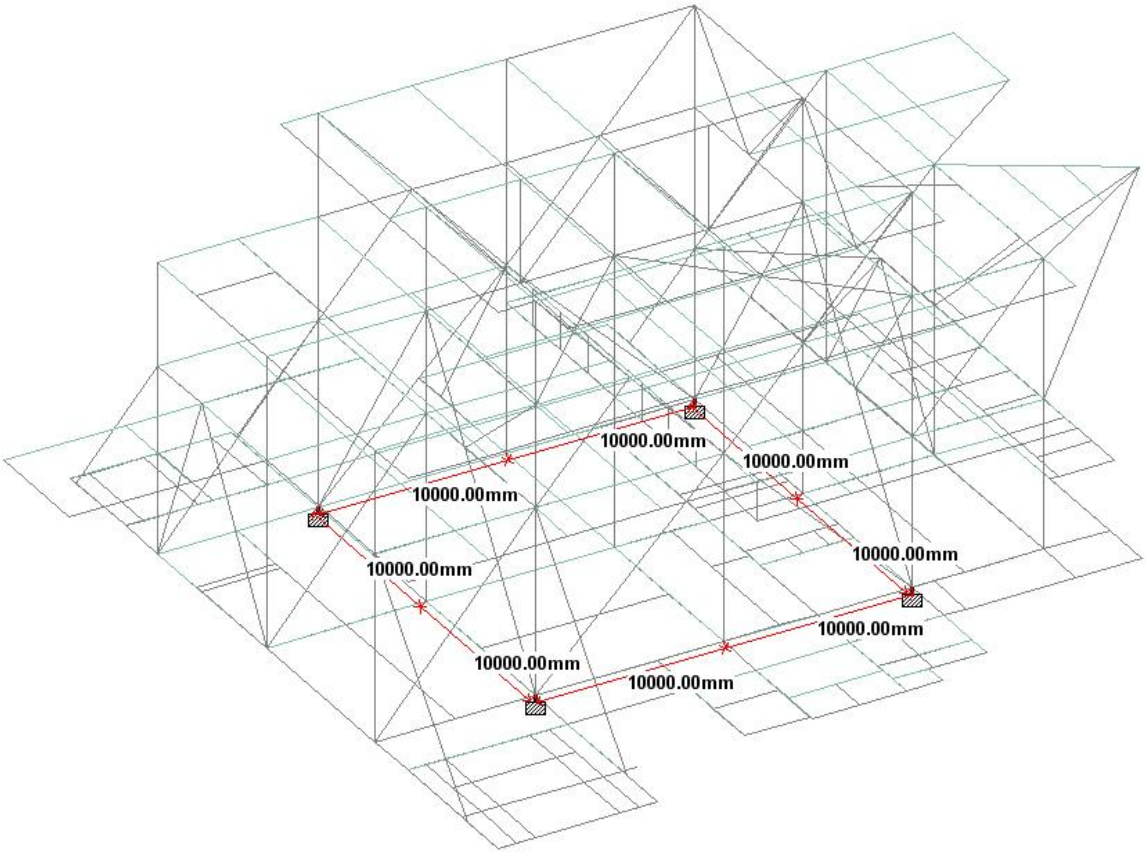


Figure 4.3 - The supports of the platform.

4.4.Plates

The plates are modeled after the drawings and the platform has plates with thickness of 8mm, 10mm and 12mm. The plates are modeled in the center of each beam, so the plates don't contribute to the EI in the beams strong axis.

To only include the shear stiffness of the plates in the global analysis, the E-module of the plates is reduced to 1% of their original value:

Table 4.4.1 - E-module of the plates.

E-module:
205000 N/mm^2 * 1% = <u>2050 N/mm^2</u>

Table 4.4.2 - Number of plates.

Number of plates:	
8mm	34
10mm	56
12mm	1
Total	91

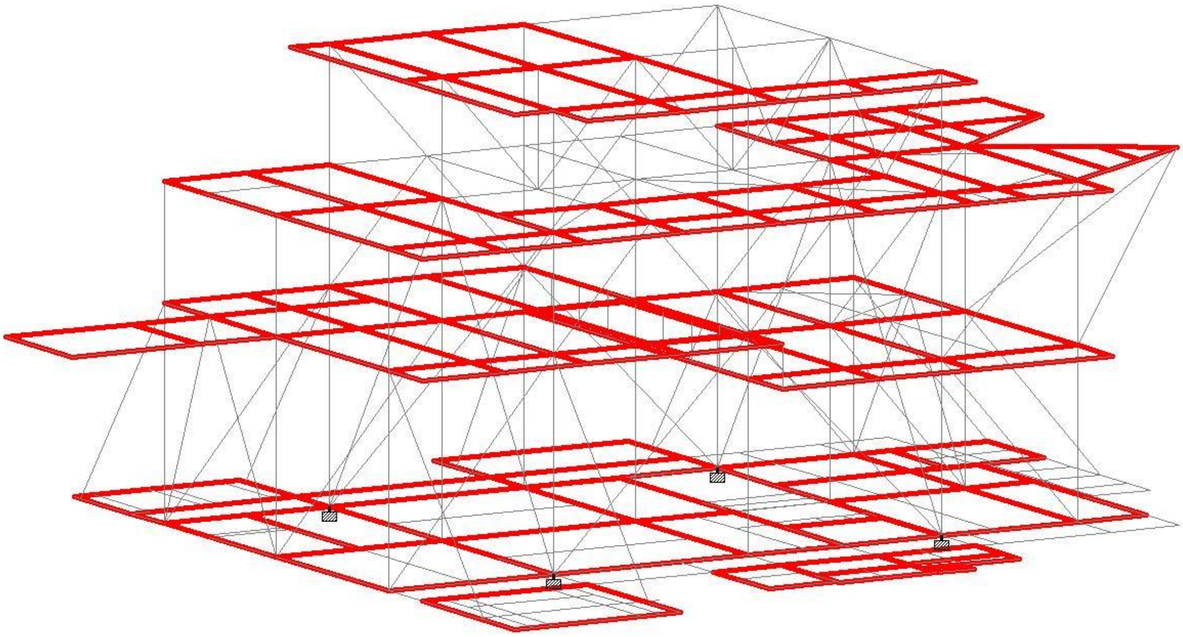


Figure 4.4.1 - All of the plates.

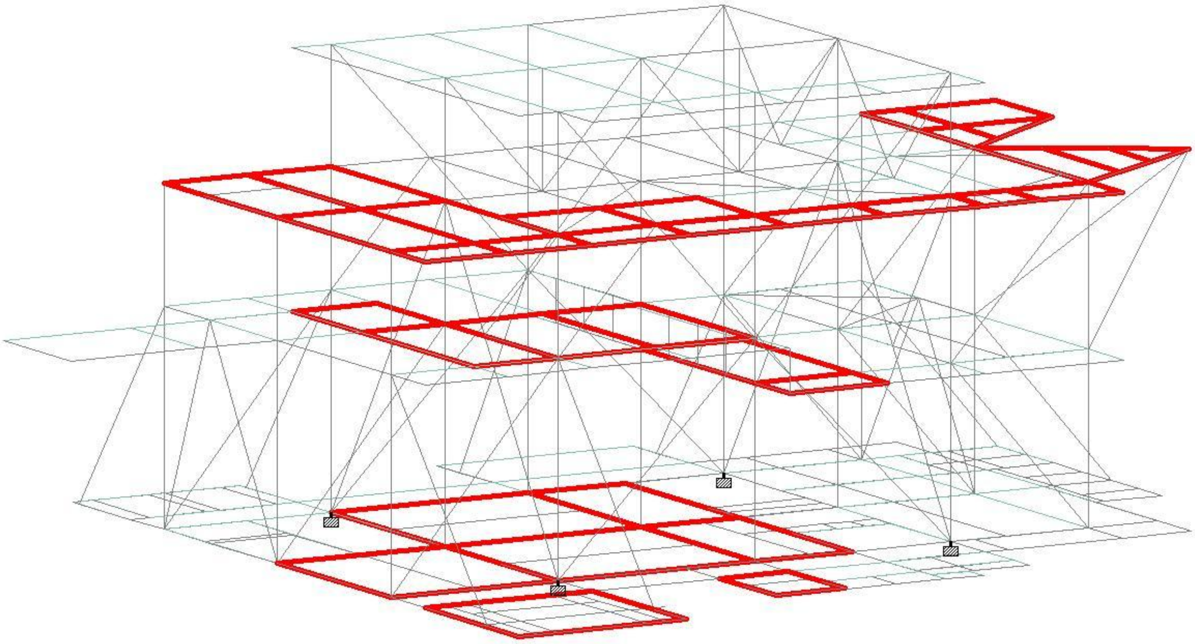


Figure 4.4.2 - 8mm plates.

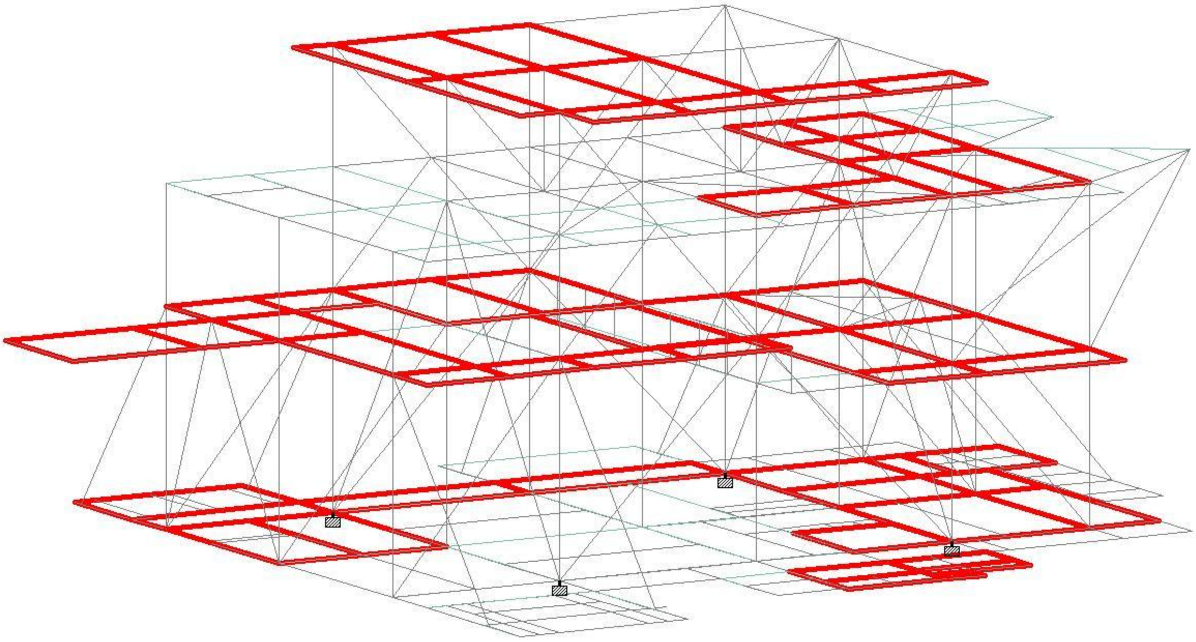


Figure 4.4.3 - 10mm plates.

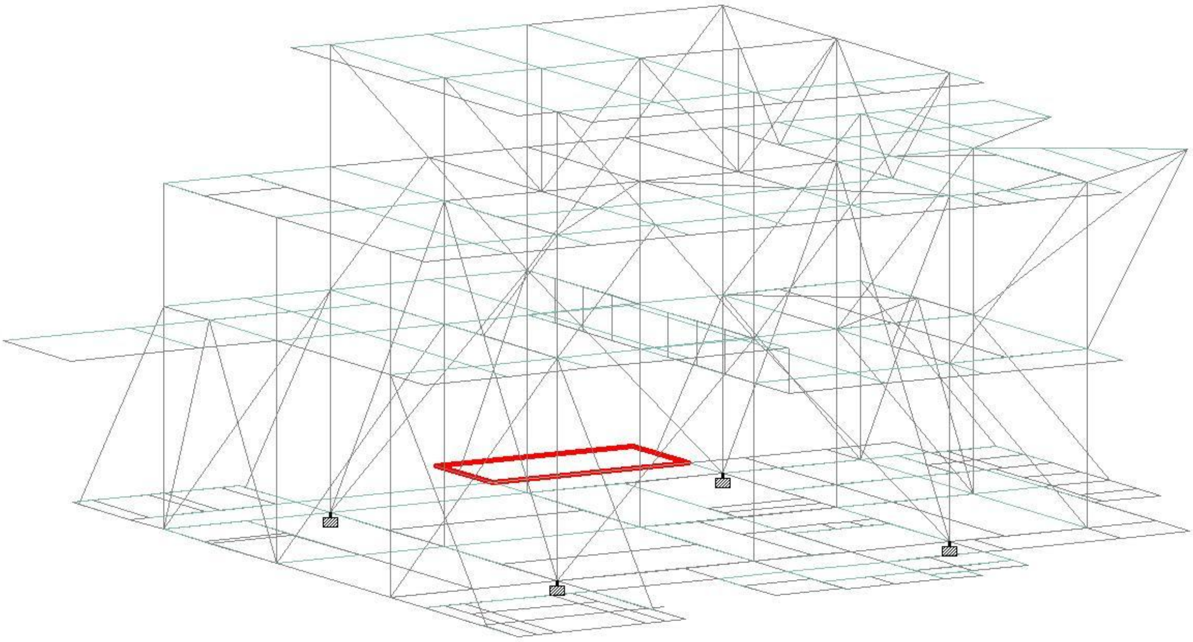


Figure 4.4.4 - 12mm plate.

4.5.Cross sections

The platform consists of custom cross sections and standard HEA, HEB, IPE, UPN and RHS sections. The bearing beams of the structure, primarily consists of custom cross sections. The custom cross sections are defined in the drawings of the structure, Appendix D.

4.6.Materials

The materials used in StaadPro are presented in table 4.6:

Table 4.6 - The materials used in StaadPro.

Material	**Yield strength [N/mm^2]**	**E-module [N/mm^2]**	**Poisson's ratio**	**Density [kg/m^3]**	**Thermal expansion coefficient**
STEEL	355	205000	0.3	7.83E3	12E-6
PLATESTEEL	355	2050	0.3	7.83E3	12E-6

The material STEEL is used for all steel beams in the structure.

The material PLATESTEEL with reduced E-module, is used for every plate in the structure.

The requirements of NORSOK N-001 (2010) chapter 7.2.3 and 7.2.4 gives following material factor used respectively in ULS and SLS analyses:

ULS: $\gamma_m = 1,15$

SLS: $\gamma_m = 1,0$

5 LOADS

The loads affecting the structure consist of self weight, live loads and wind loads. Equipment loads have not been provided, so they have not been considered. The load from the self weight has been given a load factor of 1,0 in StaadPro.

5.1.Live loads

All of the live loads used in this report, is calculated from the NORSOK N-003 standard. Since the information for the live loads are not given, the live loads are assumed to be on places on the decks where they make a realistic picture of the real world. The live loads include the laydown area, storage area, walkway area, area between equipment and load from a bridge on the bridge landing. The calculations itself are presented in Appendix B.

The following chapters contain a 3D model of every deck and a figure that shows the location of where the live loads are assumed to be. A summary of the forces affecting each beam element is presented in the last chapter. The decks are presented from the top deck to the bottom deck to make the presentation more clearly.

5.1.1. Weather deck

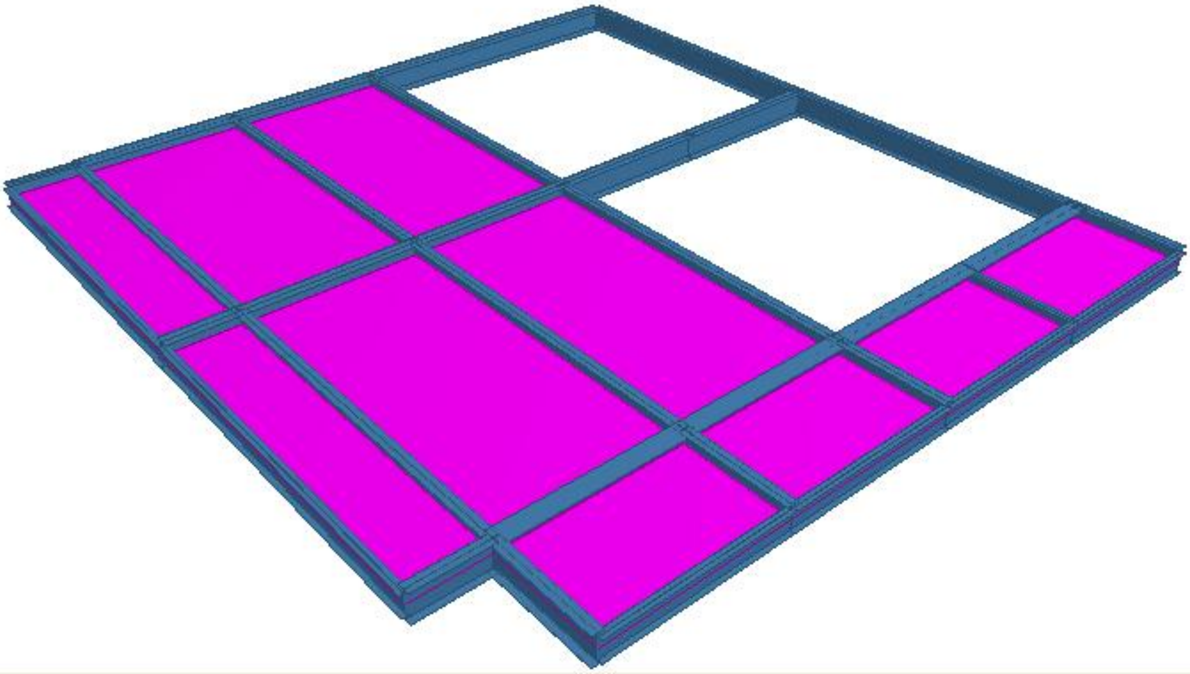


Figure 5.1.1.1 - 3D model of the weather deck.

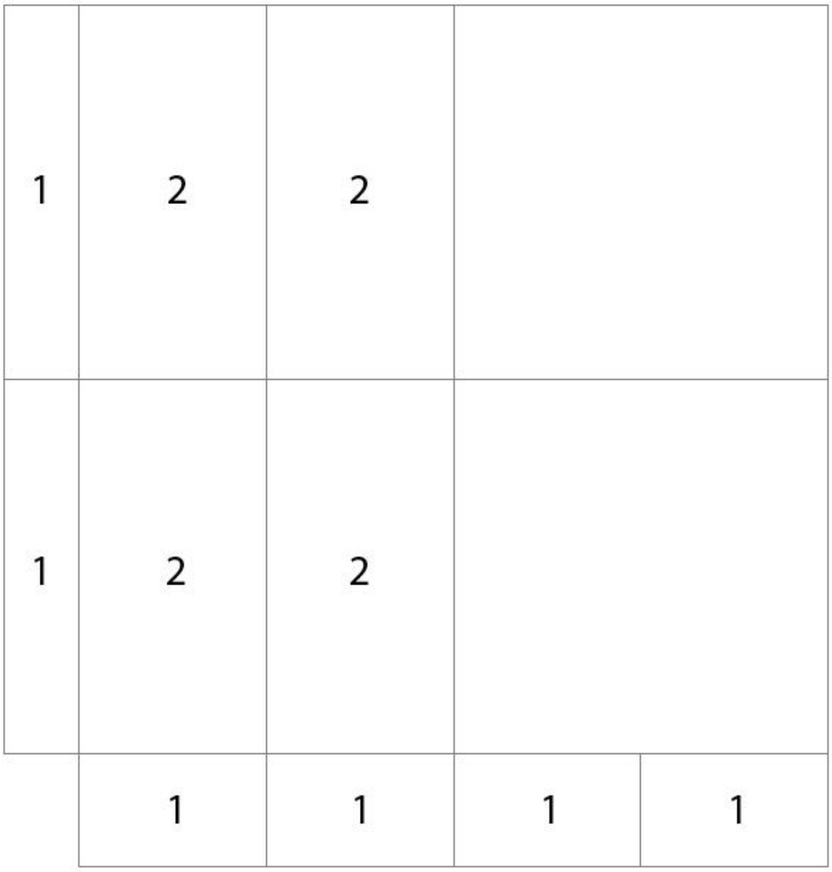


Figure 5.1.1.2 - Location of the live loads on the weather deck.

The following live loads are affecting the weather deck:

Table 5.1.1 - Weather deck live loads.

Live load:	**Force:**	**Affected girders:**
Storage area	15 kN/m^2	Area 2
Walkways, staircases and platforms	4 kN/m^2	Area 1

5.1.2. Mezzane deck

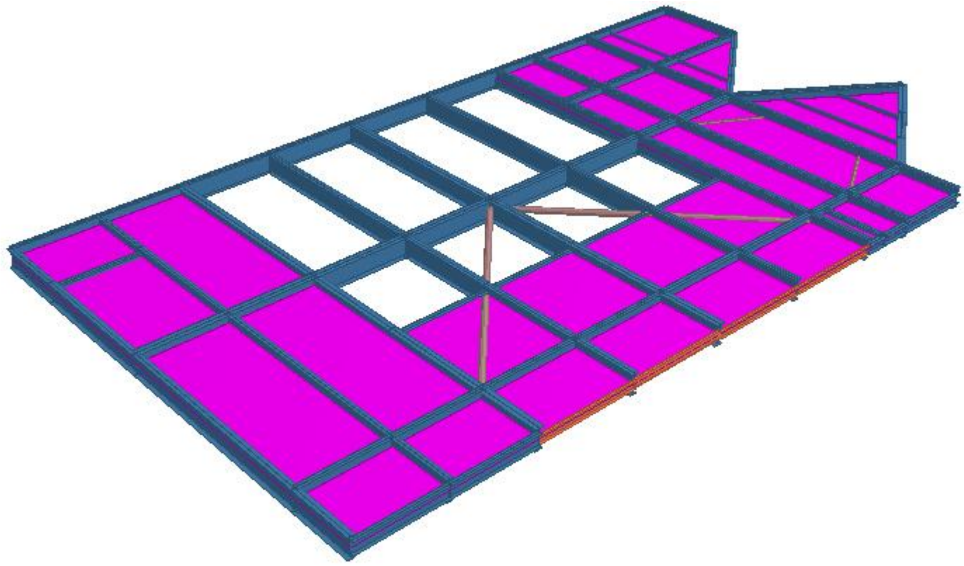


Figure 5.1.2.1 - 3D model of the mezzane deck.

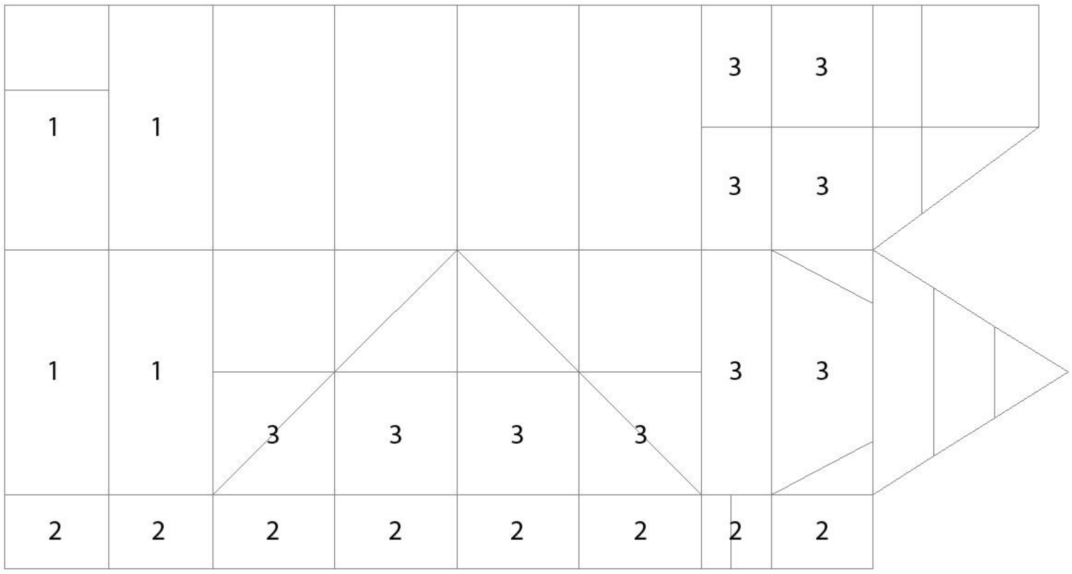


Figure 5.1.2.2 - Location of the live loads on the mezzane deck.

The following live loads are affecting the mezzane deck:

Table 5.1.2 - Mezzane deck live loads.

Live load:	**Force:**	**Affected girders:**
Storage area	15 kN/m^2	Area 3
Laydown area	15 kN/m^2	Area 1
Walkway area	4 kN/m^2	Area 2

5.1.3. Upper main deck

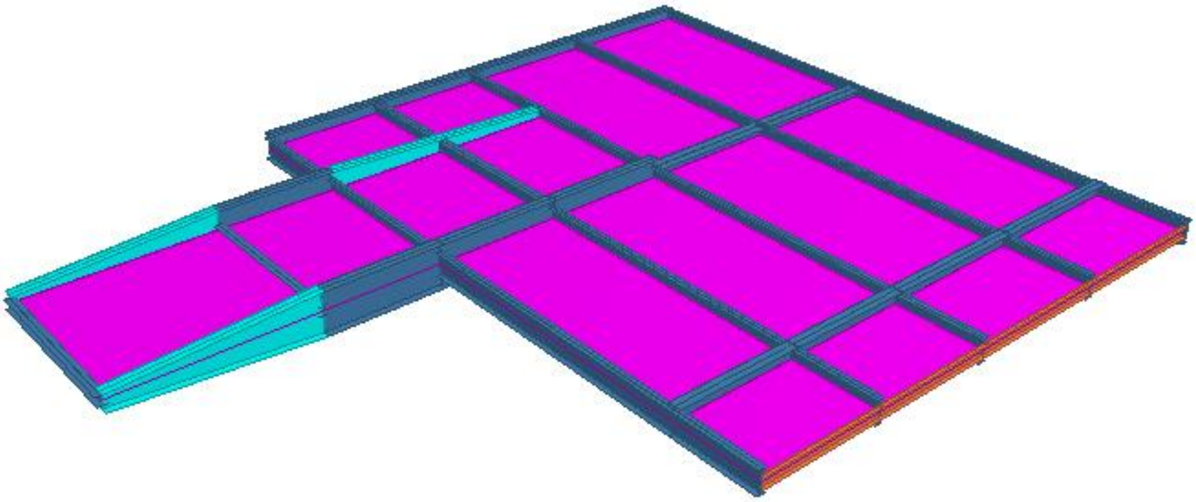


Figure 5.1.3.1 - 3D model of the upper main deck.

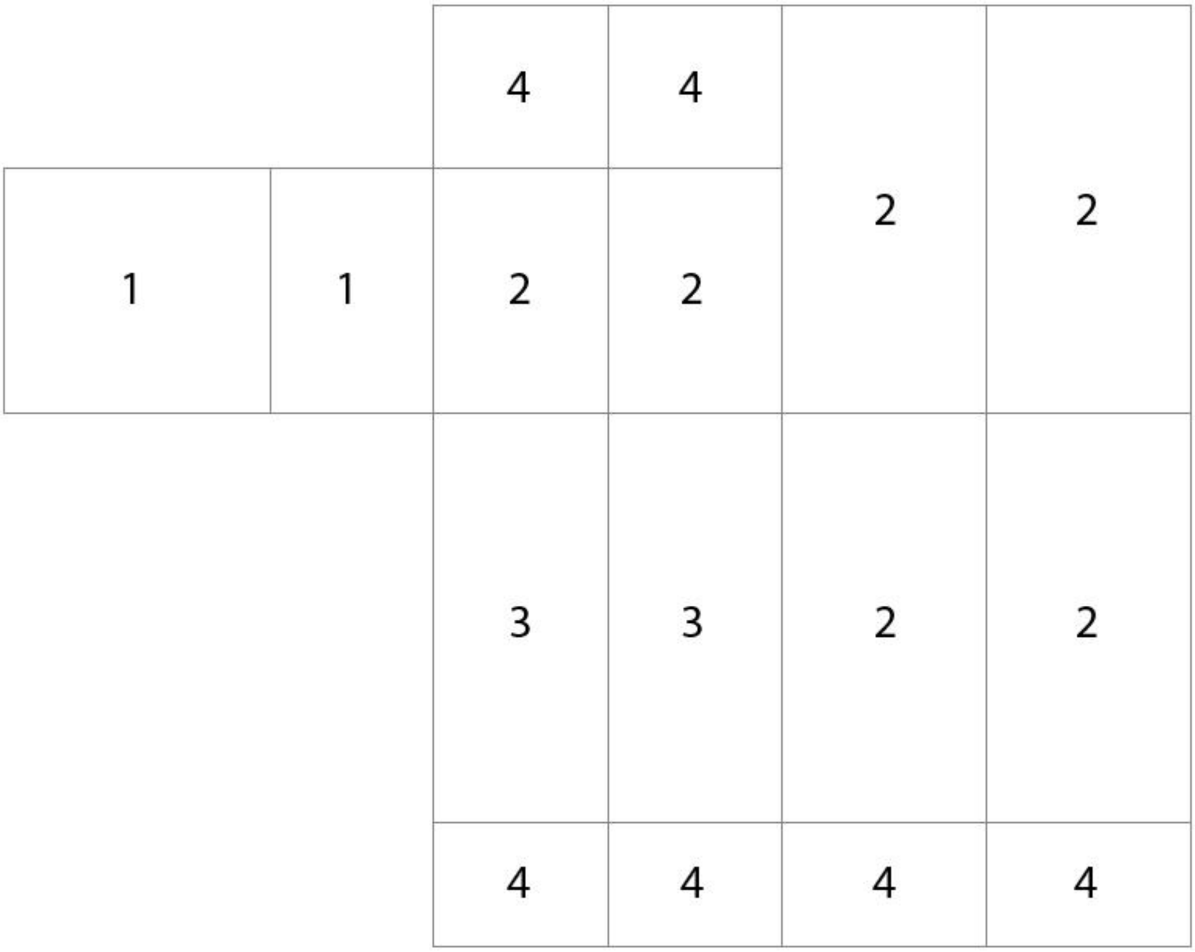


Figure 5.1.3.2 - Location of the live loads on the upper main deck.

The following live loads are affecting the upper main deck:

Table 5.1.3 -Upper main deck live loads.

Live load:	**Force:**	**Area:**
Laydown area	15 kN/m^2	1
Storage area	15 kN/m^2	2
Walkway area	4 kN/m^2	4
Area between equipment	5 kN/m^2	3

5.1.4. Lower main deck

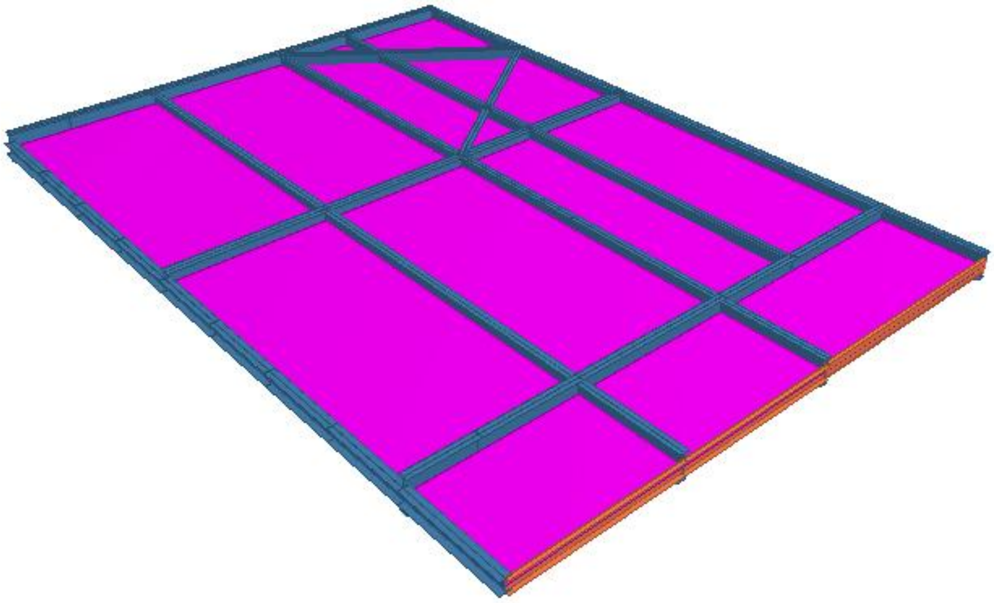


Figure 5.1.4.1 - 3D model of the lower main deck.

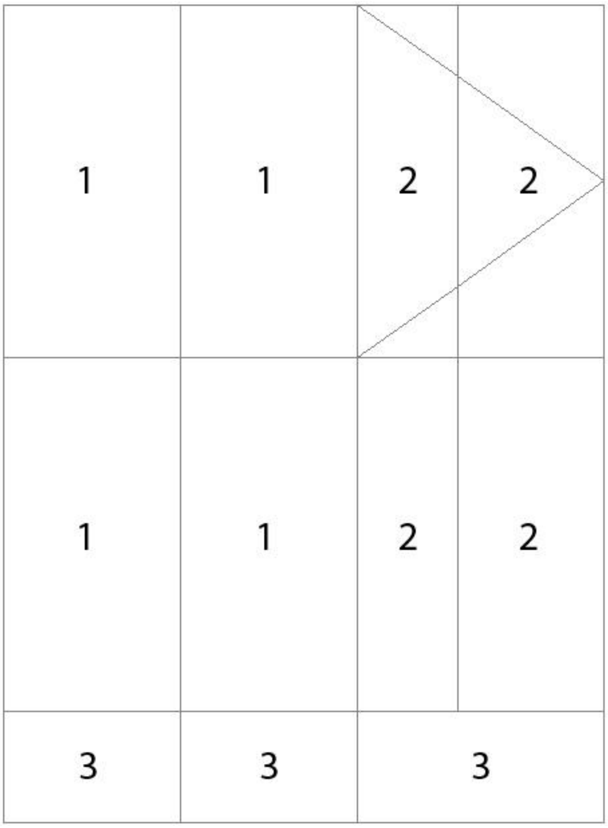


Figure 5.1.4.2 - Location of live loads on the lower main deck.

The following live loads are affecting the lower main deck:

Table 5.1.4 - Lower main deck live loads.

Live load:	**Force:**	**Area:**
Storage area	15 kN/m^2	1
Walkway area	4 kN/m^2	3
Area between equipment	5 kN/m^2	2

5.1.5. Cellar deck

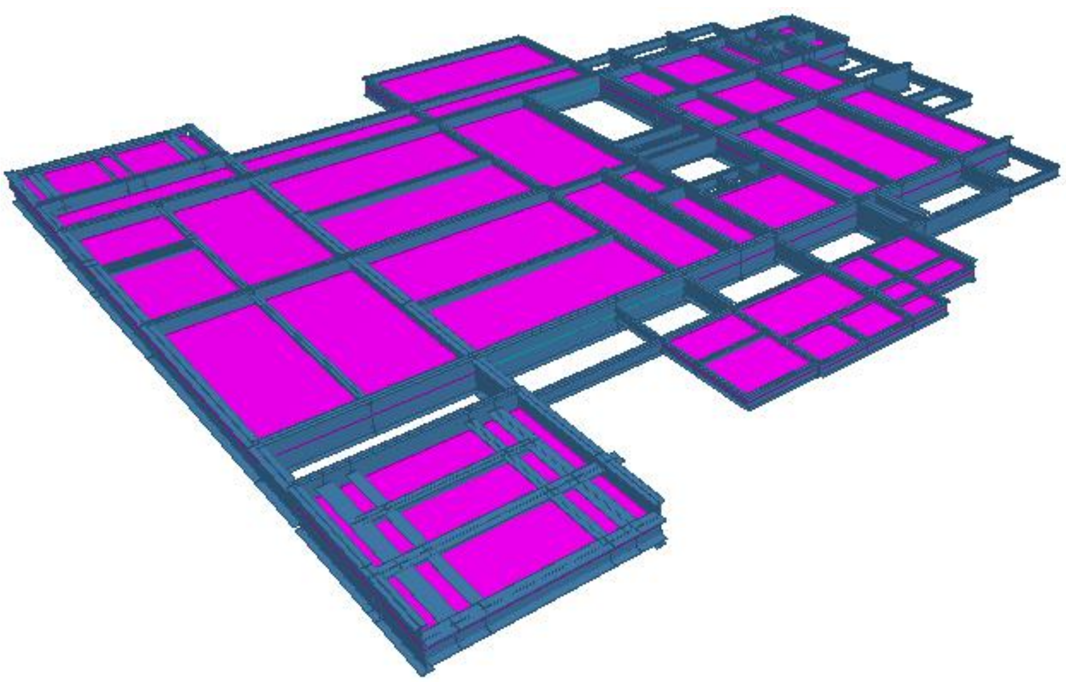


Figure 5.6.5.1 - 3D model of the cellar deck.

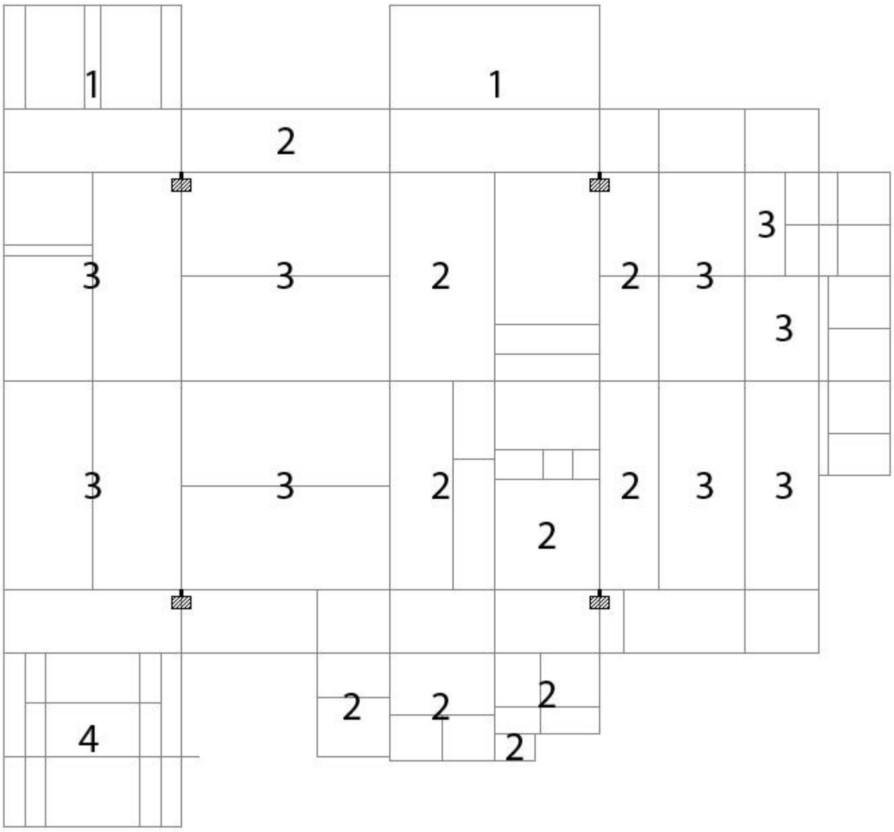


Figure 5.1.5.2 - Location of the live loads on the cellar deck.

The following live loads are affecting the cellar deck:

Table 5.1.5 - Cellar deck live loads

Live load:	Force:	Affected girders:
Storage area	15 kN/m^2	Area 3
Laydown area	15 kN/m^2	Area 1
Walkway area	4 kN/m^2	Area 2
Bridge landing	5.379 kN/m^2	Area 4

5.1.6. Summary

5.1.6.1. Weather deck

Table 5.1.6.1 shows the summary of the live loads on the weather deck.

Table 5.1.6.1 - Weather deck summary of live loads.

Weather deck:					
Storage area:					
Plategirder width, b:	300mm	400mm	500mm		
Force:	4.5 kN/m	6 kN/m	7.5 kN/m		
Walkway area:					
Plategirder width, b:	220mm	300mm	400mm	500mm	
Force:	0.88 kN/m	1.2 kN/m	1.6 kN/m	2 kN/m	

5.1.6.2. Mezzane deck

Table 5.1.6.2 shows the summary of the live loads on the mezzane deck.

Table 5.1.6.2 - Mezzane deck summary of live loads.

Mezzane deck					
Storage area:					
Plategirder widh, b:	250mm	300mm	400mm		
Force	3.75 kN/m	4.5 kN/m	6 kN/m		
Walkway area:					
Plategirder width, b:	220mm	250mm	300mm	400mm	
Force:	0.88 kN/m	1 kN/m	1.2 kN/m	1.6 kN/m	
Laydown area:					
Plategirder width, b:	250mm	300mm	400mm		
Force:	3.75 kN/m	4.5 kN/m	6 kN/m		

5.1.6.3. Upper main deck

Table 5.1.6.3 shows the summary of the live loads on the upper main deck.

Table 5.1.6.3 - Upper main deck summary of live loads.

Upper main deck					
Storage area:					
Plategirder width, b:	250mm	300mm	400mm	600mm	
Force:	3.75 kN/m	4.5 kN/m	6 kN/m	9 kN/m	
Walkway area:					
Plategirder width, b:	250mm	300mm	400mm		
Force:	1 kN/m	1.2 kN/m	1.6 kN/m		
Laydown area:					
Plategirder width, b:	250mm	300mm	400mm		
Force:	3.75 kN/m	4.5 kN/m	6 kN/m		
Area between equipment:					
Plategirder width, b:	250mm	400mm			
Force:	1.25 kN/m	2 kN/m			

5.1.6.4. Lower main deck

Table 5.1.6.4 shows the summary of the live loads on the lower main deck.

Table 5.1.6.4 - Lower main deck summary of live loads.

Lower main deck				
Storage area:				
Plategirder width, b:	250mm	300mm	400mm	
Force:	3.75 kN/m	4.5 kN/m	6 kN/m	
Walkway area:				
Plategirder width, b:	200mm	250mm	300mm	
Force:	0.8 kN/m	1 kN/m	1.2 kN/m	
Area between equipment:				
Plategirder width, b:	250mm	300mm	400mm	
Force:	1.25 kN/m	1.5 kN/m	2 kN/m	

5.1.6.5. Cellar deck

Table 5.1.6.5 shows the summary of the live loads on the lower main deck.

Table 5.2.6.5 - Cellar deck summary of live loads.

Cellardeck					
Storage area:					
Plategirder width, b:	200mm	300mm	400mm	500mm	
Force:	3 kN/m	4.5 kN/m	6 kN/m	7.5 kN/m	
Walkway area:					
Plategirder width, b:	200mm	220mm	300mm	400mm	500mm
Force:	0.8 kN/m	0.88 kN/m	1.2 kN/m	1.6 kN/m	2 kN/m
Laydown area:					
Plategirder width, b:	200mm	300mm	400mm	500mm	600mm
Force:	3 kN/m	4.5 kN/m	6 kN/m	7.5 kN/m	9 kN/m

5.2.Wind loads

The wind loads affecting the platform are calculated only for the outer horizontal beams on each of the decks.

5.2.1. Wind statistics near the Draupner field

The following table shows the percentage distribution of the wind speed and wind direction. The data are based on modeled data from the years 1958-2009.

Table 5.2.1 - Wind speed statistics.

Windspeed	**Direction**								
m/s	N	NE	E	SE	S	SW	W	NW	OMNI
0-3	0,86	0,79	0,69	0,72	0,86	0,89	0,91	0,92	6,64
3-6	2,83	1,73	1,89	2,33	3,22	3,16	2,77	3,05	20,98
6-9	3,67	1,25	1,68	3,17	4,64	4,30	3,63	4,31	26,64
9-12	3,09	0,48	1,20	3,07	3,63	3,63	3,37	3,78	22,25
12-15	1,65	0,14	0,72	2,43	2,22	2,42	2,20	2,22	14,01
15-18	0,56	0,02	0,35	1,34	0,92	1,10	1,00	0,86	6,14
18-21	0,19	0,01	0,13	0,63	0,32	0,40	0,39	0,39	2,45
21-24	0,05	0,00	0,05	0,23	0,08	0,11	0,13	0,10	0,74
24-27	0,01	0,00	0,01	0,04	0,01	0,01	0,02	0,02	0,13
27-30	0,00	-	0,01	-	-	0,00	0,01	0,01	0,02
>30	-	-	-	-	-	0,00	0,00	0,00	0,00
TOTAL	12,89	4,41	6,74	13,94	15,89	16,03	14,43	15,66	100,00

5.2.2. Wind rose

A presentation of the wind, a wind rose (See figure 5.2.2.1), is created from table 5.2.1 to see which direction the wind is dominant.

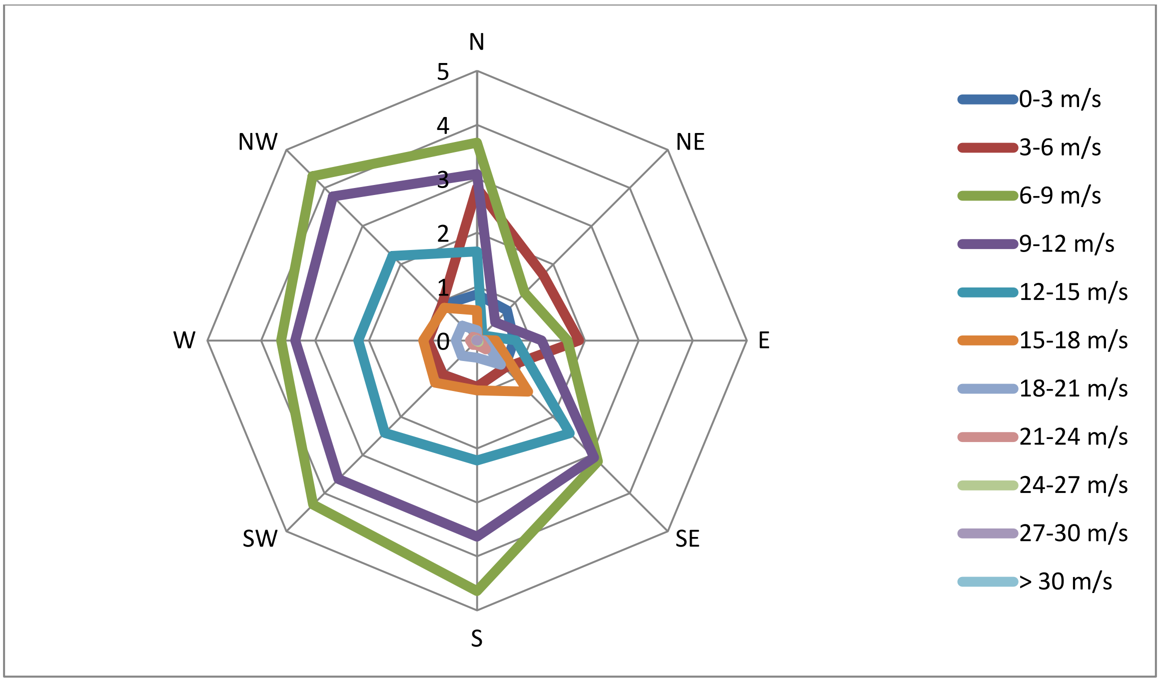


Figure 5.2.2.1 – Wind rose.

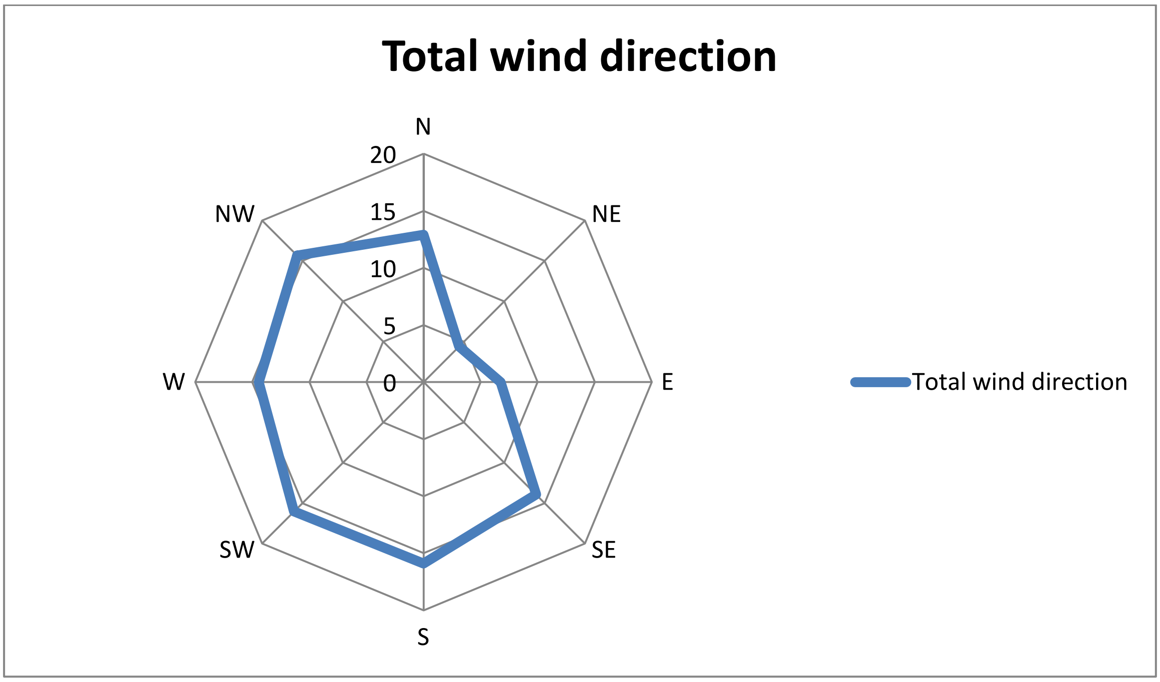


Figure 5.2.2.2 – Total wind direction.

For the calculation of the force caused by the wind, it’s important to know where the majority of the wind comes from. As seen from the windrose, the majority of the wind occurs in the area NW – W – SW – S – SE. For simplicity, the wind direction chosen for the calculation is North West (NW), South West (SW) and South East (SE).

The data (Table 5.2.1) was given in such a late period of the semester, so the wind speed for calculating the wind force is set to 38 m/s (1 hour average) according to the regulations of NORSOK N-003.

5.2.3. Summary of wind load calculations

The following loads are calculated by the regulations of NORSOK N-003 and the calculation itself is presented in Appendix A. The wind loads from the calculations are given in kN/m^2, and then multiplied with the height of each plate girder. This is conducted due to get the loads per length meter.

Table 5.2.3.1 shows the height above sea level for each deck and the wind velocity at these heights.

Table 5.2.3.1 - Summary of wind velocities at the different decks.

Deck:	**Height above sealevel, z:**	**Shape factor, C:**	**Turbulence intensity factor, I_u:**	**1 hour mean wind speed, U(z):**	**Characteristic wind velocity u(z,t):**
Cellar deck	30m	0.148	0.124	44.192 m/s	60.135 m/s
Lower main deck	38m	0.148	0.118	45.524 m/s	61.116 m/s
Upper main deck	40m	0.148	0.116	45.813 m/s	61.328 m/s
Mezzane deck	45.5m	0.148	0.113	46.539 m/s	61.859 m/s
Weather deck	51m	0.148	0.110	47.182 m/s	62.329 m/s

Table 5.2.3.2 shows the wind loads per length meter on beam element for every deck.

Table 5.2.3.2 - Wind loads per length meter.

Cellardeck:							
Plategirder height, h:	500mm	600mm	700mm	800mm	1000mm	1500mm	1800mm
Force:	1.981 kN/m	2.377 kN/m	2.773 kN/m	3.169 kN/m	3.961 kN/m	5.942 kN/m	7.130 kN/m
Lower main deck:							
Plategirder height, h:	400mm	500mm	800mm	1000mm			
Force:	1.637 kN/m	2.046 kN/m	3.273 kN/m	4.091 kN/m			
Upper main deck:							
Plategirder height, h:	340mm	400mm	800mm	1000mm	1500mm		
Force:	1.401 kN/m	1.648 kN/m	3.296 kN/m	4.120 kN/m	6.180 kN/m		
Mezzane deck:							
Plategirder height, h:	400mm	450mm	600mm	1000mm			
Force:	1.677 kN/m	1.886 kN/m	2.515 kN/m	4.192 kN/m			
Weather deck:							
Plategirder height, h:	600mm	800mm					
Force:	2.553 kN/m	3.404 kN/m					

5.3.Bridge landing

The load affecting the platforms bridge landing, is found from a bridge used between the Ekofisk K and Ekofisk B platform at the Ekofisk field. The bridge is just an example used for the purpose of finding a suitable load for the bridge landing.

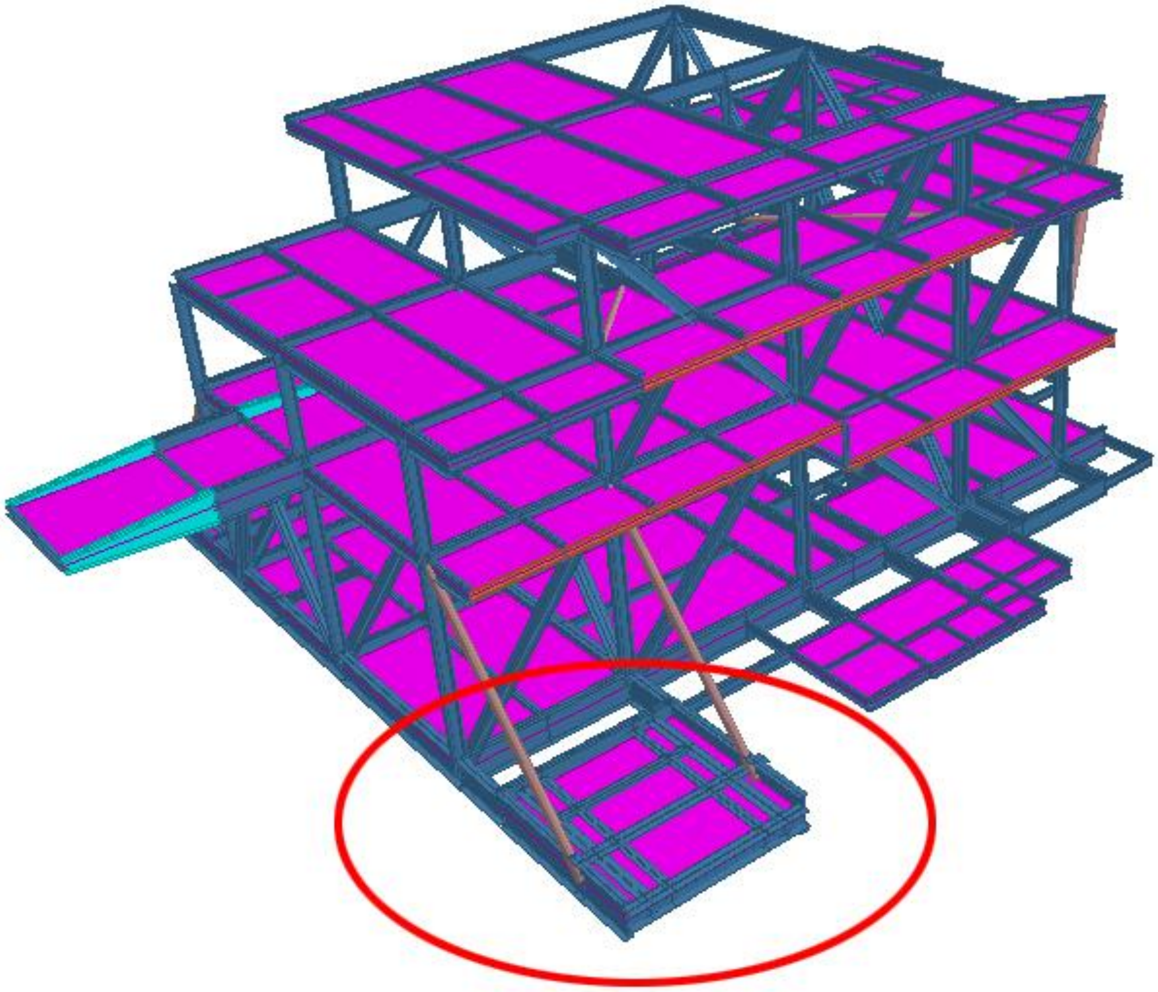


Figure 5.3.1 - The location of the bridge landing on the platform.

The selfweight of the bridge is given as 2958,5 kN. The bridge is 110m long and 5m wide and the bridge landing is 8,5m long and 8,29m wide. The force from the bridge is calculated as four nodal forces, one on each corner of the bridge landing:

Selfweight bridge:

$$q_{selfweight} := 2958.5kN$$

Area of bridge:

$$A_{bridge} := 110m \cdot 5m = 550m^2$$

Load per m^2:

$$q_{bridge} := \frac{q_{selfweight}}{A_{bridge}} = 5.379 \frac{kN}{m^2}$$

Area of bridgelanding:

$$A_{bridgelanding} := 8.5m \cdot 8.29m = 70.465m^2$$

Force from bridge:

$$F_{bridge} := q_{bridge} \cdot A_{bridgelanding} = 379.038kN$$

Force per corner:

$$F_{corner} := \frac{F_{bridge}}{4} = 94.759kN$$

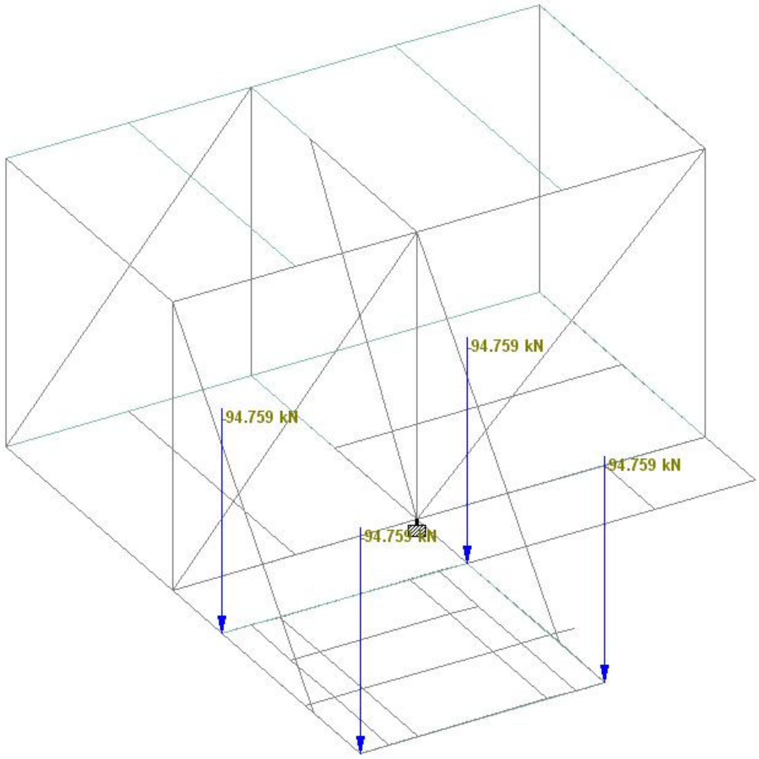


Figure 5.3.2 - The loads on the bridge landing.

The platform is checked to see if there is a better location for the bridge landing. It is checked for its initial location of the bridge landing compared to one other location. A total of two locations of the bridge landing is checked and compared with each other (See figure 5.3.1.1 and 5.3.2.1).

When finding the other location for the bridge landing, it is assumed that the other platform that is connected to the Draupner platform has not yet been built. The placement of the other platform has not been decided, so it will not affect the finding of another location for the bridge landing.

5.3.1. Location 1

This is the actual placement of the bridge landing at the Draupner platform and the results from the analysis will be compared to this location.

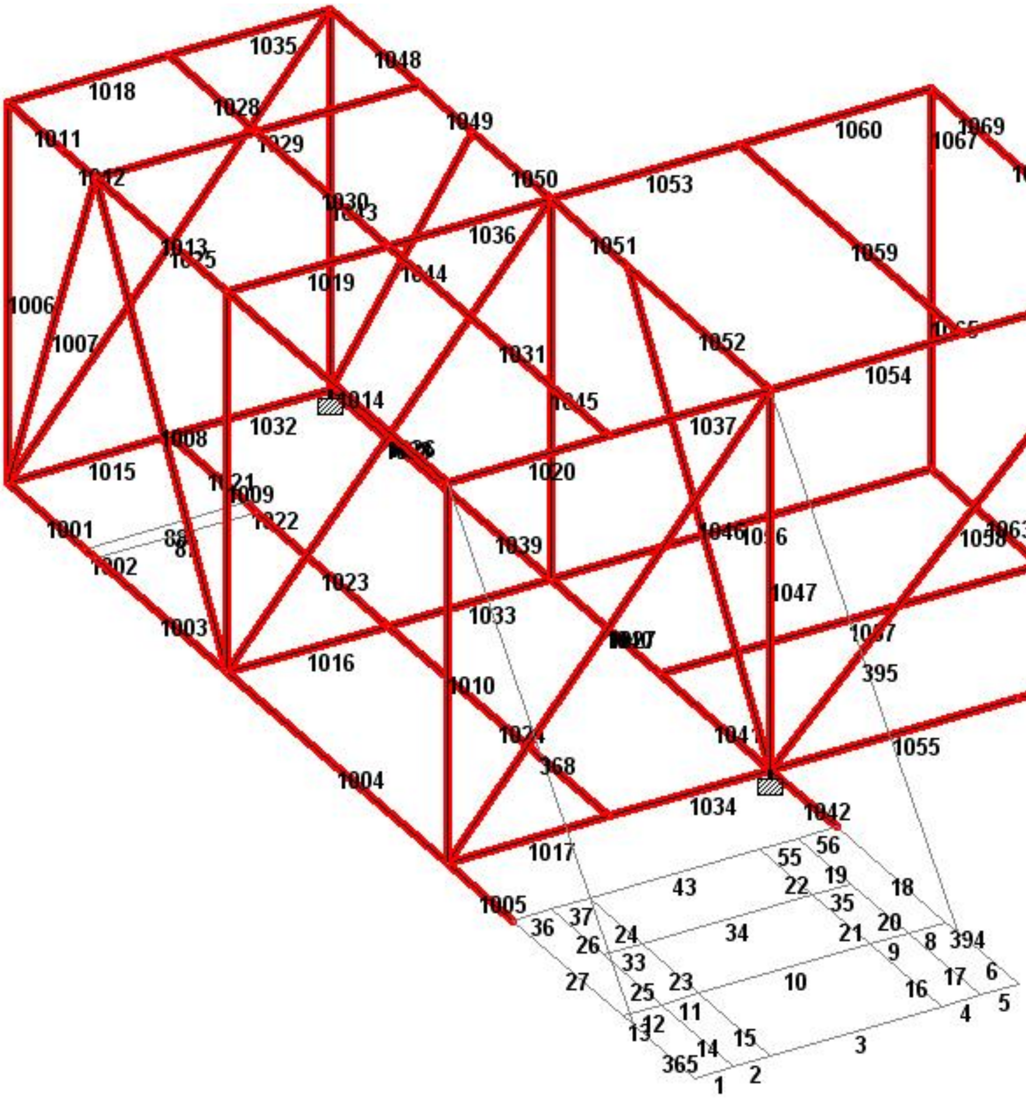


Figure 5.3.1.1 – The placement of the bridge landing at location 1.

5.3.2. Location 2a

Because of the movement of the bridge landing in location 2a, some of the beams are divided into more and smaller beams. Beam 1004 from location 1 is now beam 1119, 1120, 1121, 1122, 1123 and 1124. Beam 1014 from location 1 is now beam 1014 and 1117.

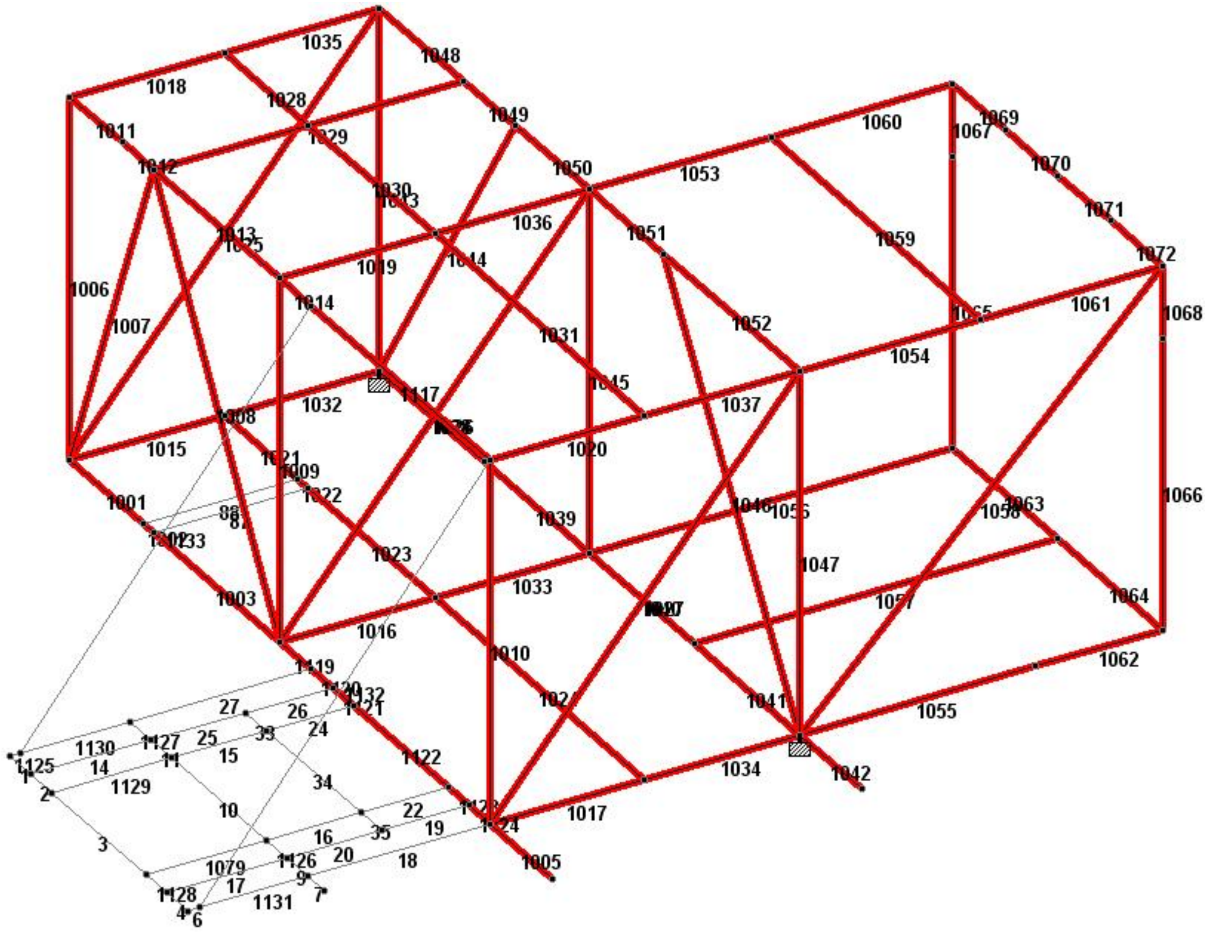


Figure 5.3.2.1 - The location of the bridge landing at location 2a.

5.4.Load from crane and tower

As seen from figure 2.1, the Draupner E platform includes a crane and tower. The high tower will be exposed for massive wind which can lead to VIV. This will cause fatigue damage to the tower itself and also to the structure beneath. The crane can also experience VIV, and the structure beneath both the tower and the crane, has to be strong enough to withstand these forces. The structure also has to withstand the moment created by the wind on both the crane and the tower. Lifting operations of the crane will also create moments the structure has to withstand.

The specifications for the crane and the tower have not been provided. Therefore, the load effects from the crane and the tower will not be considered.

5.5.Load combinations

The load combinations used in this thesis is presented in table 5.5. The load factors used for each combination are found in NORSOK N-001 Table 1 – Partial action factors for the limit states.

For the different locations, there have been two additional ULS load combinations and one additional SLS load combination:

ULS:

One combination with the bridge landing, and one combination without both the bridge landing and the bridge itself. This is done in addition to the load combinations presented in table 5.5.

SLS:

A combination without the bridge landing and the bridge is done in addition to the load combinations presented in table 5.5.

Table 5.5 - Load combinations.

Comb	Combination L/C Name	Primary	Primary L/C Name	Factor
1000	ULS-A WIND NORTH WEST	100	DEADWEIGHT	1,3
		110	BRIDGELANDING	1,3
		200	WALKWAY WD	1,3
		210	WALKWAY MD	1,3
		220	WALKWAY UMD	1,3
		230	WALKWAY LMD	1,3
		240	WALKWAY CD	1,3
		300	STORAGE WD	1,3
		310	STORAGE MD	1,3
		320	STORAGE UMD	1,3
		330	STORAGE LMD	1,3
		340	STORAGE CD	1,3
		400	LAYDOWN MD	1,3
		410	LAYDOWN UMD	1,3
		420	LAYDOWN CD	1,3
		500	EQUIPMENT UMD	1,3
		510	EQUIPMENT LMD	1,3
		600	NW WD	0,7
		610	NW MD	0,7
		620	NW UMD	0,7

		630	NW LMD	0,7
		640	NW CD	0,7
1100	ULS-A WIND SOUTH WEST	100	DEADWEIGHT	1,3
		110	BRIDGELANDING	1,3
		200	WALKWAY WD	1,3
		210	WALKWAY MD	1,3
		220	WALKWAY UMD	1,3
		230	WALKWAY LMD	1,3
		240	WALKWAY CD	1,3
		300	STORAGE WD	1,3
		310	STORAGE MD	1,3
		320	STORAGE UMD	1,3
		330	STORAGE LMD	1,3
		340	STORAGE CD	1,3
		400	LAYDOWN MD	1,3
		410	LAYDOWN UMD	1,3
		420	LAYDOWN CD	1,3
		500	EQUIPMENT UMD	1,3
		510	EQUIPMENT LMD	1,3
		700	SW WD	0,7
		710	SW MD	0,7
		720	SW UMD	0,7
		730	SW LMD	0,7
		740	SW CD	0,7
1200	ULS-A WIND SOUTH EAST	100	DEADWEIGHT	1,3
		110	BRIDGELANDING	1,3
		200	WALKWAY WD	1,3
		210	WALKWAY MD	1,3
		220	WALKWAY UMD	1,3
		230	WALKWAY LMD	1,3
		240	WALKWAY CD	1,3
		300	STORAGE WD	1,3
		310	STORAGE MD	1,3
		320	STORAGE UMD	1,3
		330	STORAGE LMD	1,3
		340	STORAGE CD	1,3
		400	LAYDOWN MD	1,3
		410	LAYDOWN UMD	1,3
		420	LAYDOWN CD	1,3
		500	EQUIPMENT UMD	1,3
		510	EQUIPMENT LMD	1,3
		800	SE WD	0,7
		810	SE MD	0,7
		820	SE UMD	0,7
		830	SE LMD	0,7
		840	SE CD	0,7
2000	ULS-B WIND NORTH WEST	100	DEADWEIGHT	1

		110	BRIDGELANDING	1
		200	WALKWAY WD	1
		210	WALKWAY MD	1
		220	WALKWAY UMD	1
		230	WALKWAY LMD	1
		240	WALKWAY CD	1
		300	STORAGE WD	1
		310	STORAGE MD	1
		320	STORAGE UMD	1
		330	STORAGE LMD	1
		340	STORAGE CD	1
		400	LAYDOWN MD	1
		410	LAYDOWN UMD	1
		420	LAYDOWN CD	1
		500	EQUIPMENT UMD	1
		510	EQUIPMENT LMD	1
		600	NW WD	1,3
		610	NW MD	1,3
		620	NW UMD	1,3
		630	NW LMD	1,3
		640	NW CD	1,3
2100	ULS-B WIND SOUTH WEST	100	DEADWEIGHT	1
		110	BRIDGELANDING	1
		200	WALKWAY WD	1
		210	WALKWAY MD	1
		220	WALKWAY UMD	1
		230	WALKWAY LMD	1
		240	WALKWAY CD	1
		300	STORAGE WD	1
		310	STORAGE MD	1
		320	STORAGE UMD	1
		330	STORAGE LMD	1
		340	STORAGE CD	1
		400	LAYDOWN MD	1
		410	LAYDOWN UMD	1
		420	LAYDOWN CD	1
		500	EQUIPMENT UMD	1
		510	EQUIPMENT LMD	1
		700	SW WD	1,3
		710	SW MD	1,3
		720	SW UMD	1,3
		730	SW LMD	1,3
		740	SW CD	1,3
2200	ULS-B WIND SOUTH EAST	100	DEADWEIGHT	1
		110	BRIDGELANDING	1
		200	WALKWAY WD	1
		210	WALKWAY MD	1

		220	WALKWAY UMD	1
		230	WALKWAY LMD	1
		240	WALKWAY CD	1
		300	STORAGE WD	1
		310	STORAGE MD	1
		320	STORAGE UMD	1
		330	STORAGE LMD	1
		340	STORAGE CD	1
		400	LAYDOWN MD	1
		410	LAYDOWN UMD	1
		420	LAYDOWN CD	1
		500	EQUIPMENT UMD	1
		510	EQUIPMENT LMD	1
		800	SE WD	1,3
		810	SE MD	1,3
		820	SE UMD	1,3
		830	SE LMD	1,3
		840	SE CD	1,3
3000	SLS WIND NORTH WEST	100	DEADWEIGHT	1
		110	BRIDGELANDING	1
		200	WALKWAY WD	1
		210	WALKWAY MD	1
		220	WALKWAY UMD	1
		230	WALKWAY LMD	1
		240	WALKWAY CD	1
		300	STORAGE WD	1
		310	STORAGE MD	1
		320	STORAGE UMD	1
		330	STORAGE LMD	1
		340	STORAGE CD	1
		400	LAYDOWN MD	1
		410	LAYDOWN UMD	1
		420	LAYDOWN CD	1
		500	EQUIPMENT UMD	1
		510	EQUIPMENT LMD	1
		600	NW WD	1
		610	NW MD	1
		620	NW UMD	1
		630	NW LMD	1
		640	NW CD	1
3100	SLS WIND SOUTH WEST	100	DEADWEIGHT	1
		110	BRIDGELANDING	1
		200	WALKWAY WD	1
		210	WALKWAY MD	1
		220	WALKWAY UMD	1
		230	WALKWAY LMD	1
		240	WALKWAY CD	1

		300	STORAGE WD	1
		310	STORAGE MD	1
		320	STORAGE UMD	1
		330	STORAGE LMD	1
		340	STORAGE CD	1
		400	LAYDOWN MD	1
		410	LAYDOWN UMD	1
		420	LAYDOWN CD	1
		500	EQUIPMENT UMD	1
		510	EQUIPMENT LMD	1
		700	SW WD	1
		710	SW MD	1
		720	SW UMD	1
		730	SW LMD	1
		740	SW CD	1
3200	SLS WIND SOUTH EAST	100	DEADWEIGHT	1
		110	BRDIGELANDING	1
		200	WALKWAY WD	1
		210	WALKWAY MD	1
		220	WALKWAY UMD	1
		230	WALKWAY LMD	1
		240	WALKWAY CD	1
		300	STORAGE WD	1
		310	STORAGE MD	1
		320	STORAGE UMD	1
		330	STORAGE LMD	1
		340	STORAGE CD	1
		400	LAYDOWN MD	1
		410	LAYDOWN UMD	1
		420	LAYDOWN CD	1
		500	EQUIPMENT UMD	1
		510	EQUIPMENT LMD	1
		800	SE WD	1
		810	SE MD	1
		820	SE UMD	1
		830	SE LMD	1
		840	SE CD	1
3300	SLS NO WIND	100	DEADWEIGHT	1
		110	BRIDGELANDING	1
		200	WALKWAY WD	1
		210	WALKWAY MD	1
		220	WALKWAY UMD	1
		230	WALKWAY LMD	1
		240	WALKWAY CD	1
		300	STORAGE WD	1
		310	STORAGE MD	1
		320	STORAGE UMD	1

		330	STORAGE LMD	1
		340	STORAGE CD	1
		400	LAYDOWN MD	1
		410	LAYDOWN UMD	1
		420	LAYDOWN CD	1
		500	EQUIPMENT UMD	1
		510	EQUIPMENT LMD	1

6 RESULTS

6.1.Results for ULS

The structure is checked for three different ULS conditions, one condition with the bridge landing and the bridge attached, one with the bridge landing only and one where neither the bridge landing or the bridge itself attached. The structure is also checked for two SLS conditions, one condition where the bridge landing and the bridge attached, and one where neither the bridge landing nor the bridge itself is attached.

6.1.1. Location 1

Table 6.1.1.1 shows the five elements that have the highest utilization ratio when the bridge landing and the bridge itself is attached.

Table 6.1.1.1 - Five most utilized elements.

ULS-1-1, with bridge landing and bridge				
Beam nr	Profile	Utilization	Terms	Load
1014	Custom	0,675	VMIS	2000
1012	Custom	0,545	VMIS	2000
1056	Custom	0,490	STAB	1000
1058	Custom	0,452	STAB	1200
1032	Custom	0,447	STAB	1100

Table 6.1.1.2 shows the five elements that have the highest utilization ratio when only the bridge landing is attached.

Table 6.1.1.2 - Five most utilized elements.

ULS-1-2, with the bridge landing only				
Beam nr	Profile	Utilization	Terms	Load
1014	Custom	0,639	VMIS	2000
1012	Custom	0,528	VMIS	2000
1056	Custom	0,462	STAB	1000
1032	Custom	0,448	STAB	1100
1058	Custom	0,409	STAB	1200

Table 6.1.1.3 shows the five elements that have the highest utilization ratio without the bridge landing and the bridge.

Table 6.1.1.3 - Five most utilized elements.

ULS-1-3, without the bridge landing and the bridge				
Beam nr	Profile	Utilization	Terms	Load
1014	Custom	0,707	STAB	2000
1032	Custom	0,500	STAB	1000
1012	Custom	0,487	VMIS	2000
1056	Custom	0,424	STAB	1000
1044	Custom	0,396	STAB	1200

Table 6.1.1.4 shows the comparison between the different ULS analysis. ULS-1-2 and ULS-1-3 will be compared to ULS-1-1 and the grey color will show which ratio is the highest. The gray color shows the beam that is not included in the five highest utilization ratios.

Table 6.1.1.4 - Comparison of five most utilized beams.

ULS ANALYSIS 1		**ULS-1-1, with bridge landing and bridge**		**ULS-1-2, with the bridge landing only**		**ULS-1-3, without the bridge landing and the bidge**	
Beam nr	Profile	Utilization ratio	Load	Utilization ratio	Load	Utilization ratio	Load
1014	Custom	0,675	2000	0,639	2000	0,707	2000
1012	Custom	0,545	2000	0,528	2000	0,487	2000
1056	Custom	0,490	1000	0,462	1000	0,424	1000
1058	Custom	0,452	1200	0,409	1200	0,319	1200
1032	Custom	0,447	1100	0,448	1100	0,500	1000
1044	Custom	0,346	1200	0,396	1200	0,396	1200

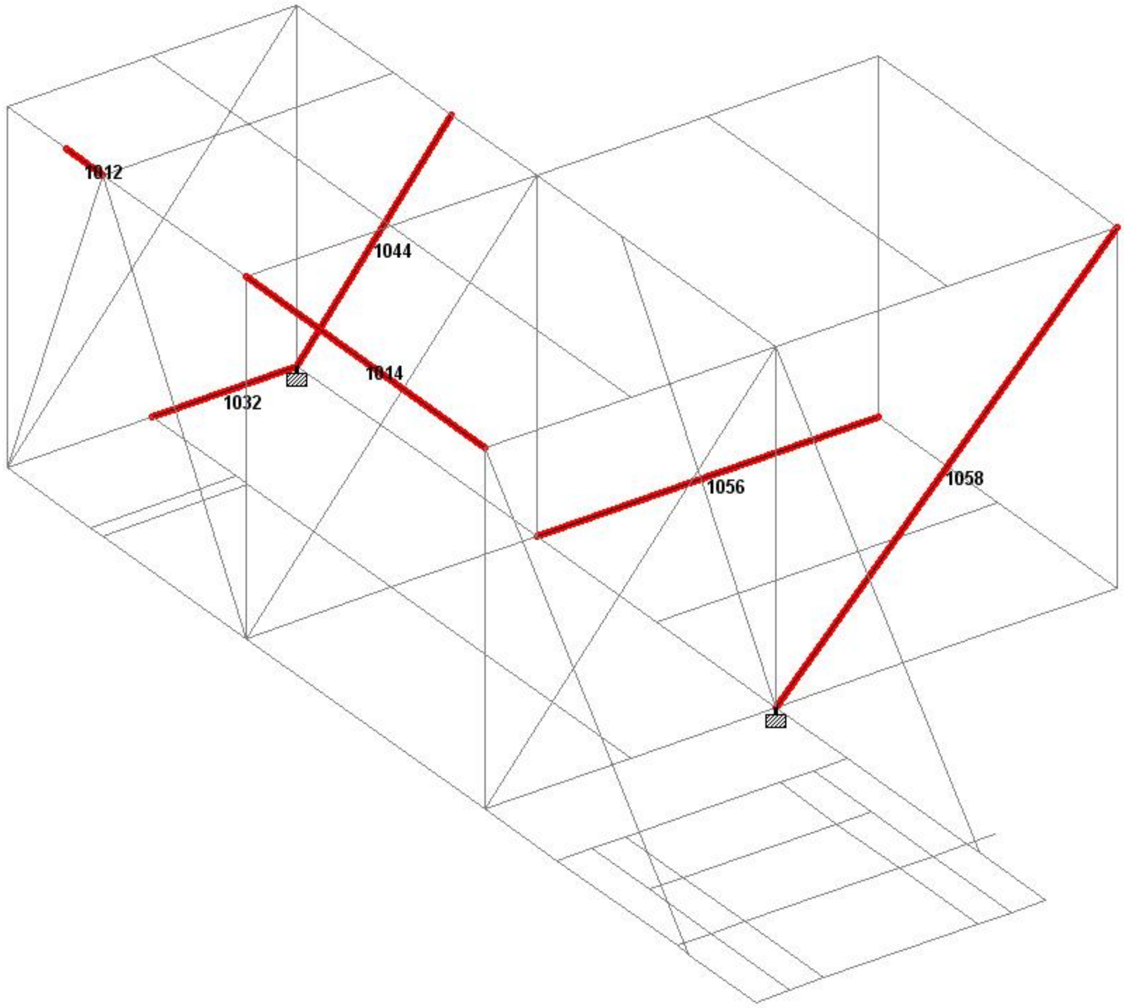


Figure 6.1.1 - The highest utilized beams in the ULS analysis for location 1.

6.1.2. Location 2a

Table 6.1.2.1 shows the five elements that have the highest utilization ratio when the bridge landing and the bridge itself is attached.

Table 6.1.2.1 - The five most utilized elements.

ULS-2-1, with bridge landing and bridge				
Beam nr	Profile	Utilization	Terms	Load
1014	Custom	3,089	VMIS	1200
1117	Custom	1,441	STAB	1000
1056	Custom	0,674	STAB	1000
1032	Custom	0,641	STAB	1100
1019	Custom	0,619	VMIS	1100

Table 6.1.2.2 shows the five elements that have the highest utilization ratio when only the bridge landing is attached.

Table 6.1.2.2 - The five most utilized elements.

ULS-2-2, with the bridge landing only				
Beam nr	Profile	Utilization	Terms	Load
1014	Custom	2.312	STAB	1000
1117	Custom	1.085	STAB	1000
1032	Custom	0.591	STAB	1100
1056	Custom	0.590	STAB	1000
1019	Custom	0.492	VMIS	1100

Table 6.1.2.3 shows the five elements that have the highest utilization ratio without the bridge landing and the bridge.

Table 6.1.2.3 - The five most utilized elements.

ULS-2-3, without the bridge landing and the bridge				
Beam nr	Profile	Utilization	Terms	Load
1117	Custom	0,656	STAB	2000
1014	Custom	0,537	VMIS	2100
1032	Custom	0,500	STAB	1000
1012	Custom	0,487	VMIS	2000
1056	Custom	0,424	STAB	1000

Table 6.1.2.4 shows the comparison between the different ULS analysis. ULS-2-2 and ULS-2-3 will be compared to ULS-2-1 and the green color will show which ratio is the highest. The gray color shows the beam that is not included in the five highest utilization ratios.

Table 6.1.2.4 - Comparison of the five most utilized elements.

ULS ANALYSIS 2a		**ULS-2-1, with bridge landing and bridge**		**ULS-2-2, with the bridge landing only**		**ULS-2-3, without the bridge landing and the bidge**	
Beam nr	Profile	Utilization ratio	Load	Utilization ratio	Load	Utilization ratio	Load
1014	Custom	3,089	1200	2,312	1000	0,537	2100
1117	Custom	1,441	1000	1,085	1000	0,656	2000
1056	Custom	0,674	1000	0,590	1000	0,424	1000
1032	Custom	0,641	1100	0,591	1100	0,500	1000
1019	Custom	0,619	1100	0,492	1100	0,320	2000
1012	Custom	0,461	2100	0,447	2100	0,487	2000

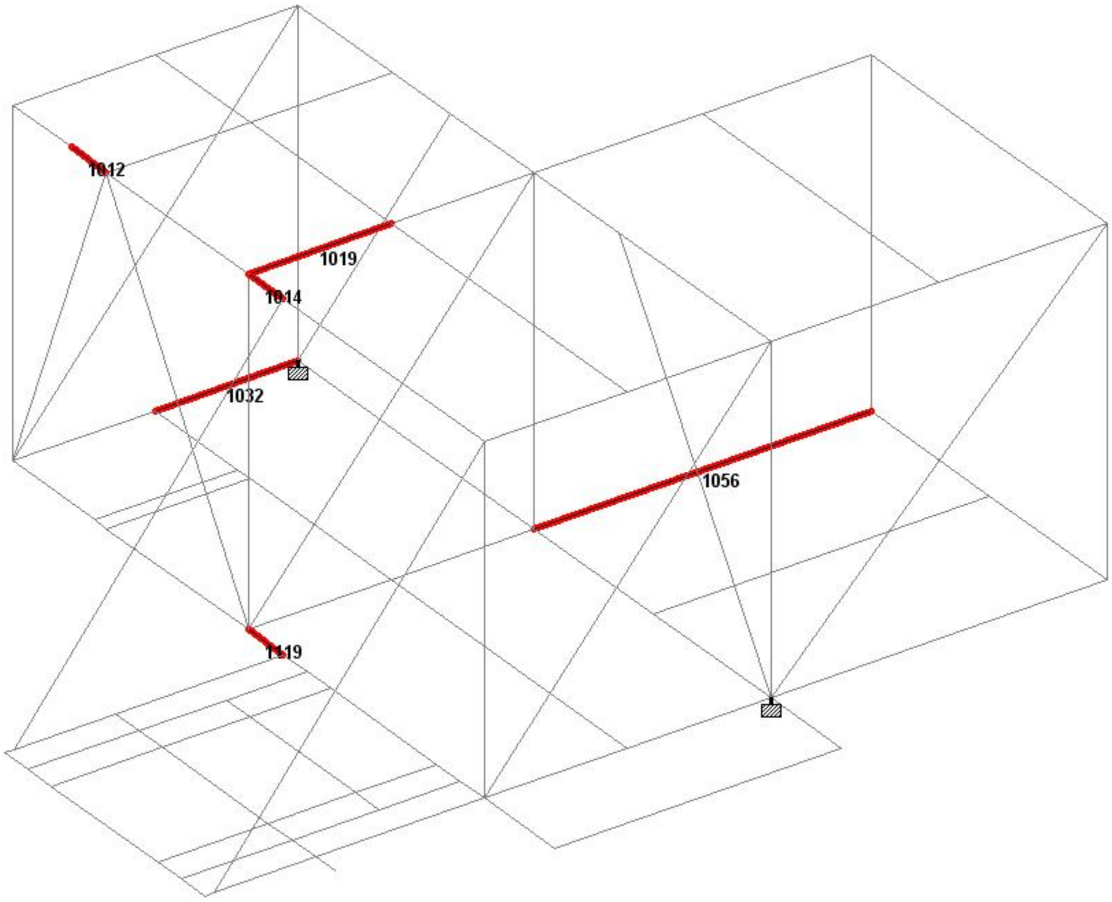


Figure 6.1.2 - The highest utilized beams in the ULS analysis for location 2a.

6.1.3. Reinforcement and adding of a new beam

As seen from the results from location 2a, beam 1014 and 1117 have a higher utilization ration than 1, and will therefore fail. The reason for this is that the beams are not able to take up the forces caused by beam 1133 (See figure 6.1.3.1). Therefore a new beam has to be added to support and take up the forces from beam 1133 that comes from the load from the bridge landing and the bridge. A new location, Location 2b, has to be checked.

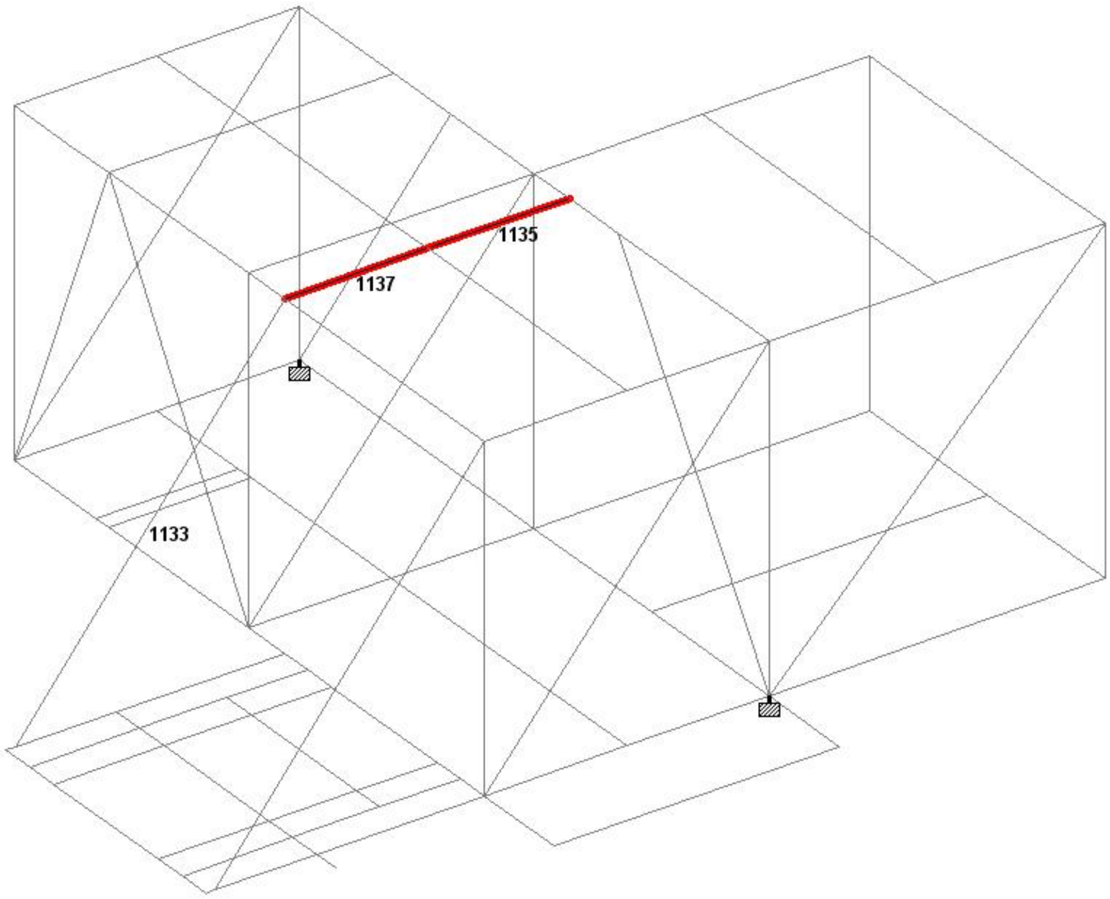


Figure 6.1.3.1 - The new added beam.

A reinforcement of beam 1014 and 1117 is also needed and the same profile that is used for beam 1020 and 1037, is used for beams 1014 and 1117 (See figure 6.1.3.2):

Table 6.1.3.1 - Beam reinforcement.

Reinforcement of beam 1014 and 1117		
	Height:	**Width:**
Section size:	1000mm	400mm
Top flange size:	30mm	400mm
Bottom flange size:	30mm	400mm
Web size:	12mm	940mm

Table 6.1.3.2 - Profile of the old beam.

Profile of the old beam		
	Height:	**Width:**
Section size:	800mm	250mm
Top flange size:	20mm	250mm
Bottom flange size:	20mm	250mm
Web size:	12mm	760mm

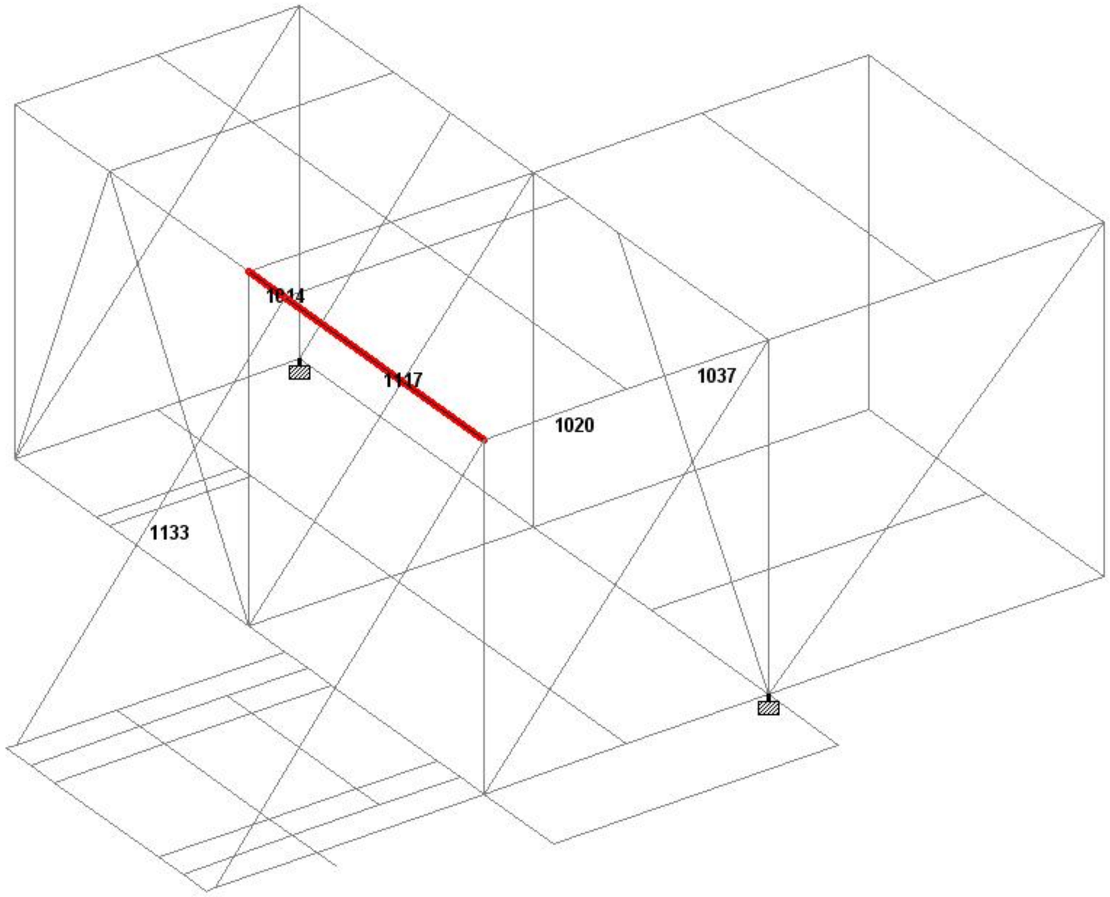


Figure 6.1.3.2 – It's the highlighted beams that needs to be reinforced.

6.1.4. Location 2b

Table 6.1.4.1 shows the five elements that have the highest utilization ratio when the bridge landing and the bridge itself is attached.

Table 6.1.4.1 - The five most utilized elements.

ULS-3-1, with bridge landing and bridge				
Beam nr	Profile	Utilization	Terms	Load
1119	Custom	0.760	VMIS	1200
1051	Custom	0.665	VMIS	1100
1056	Custom	0.660	STAB	1000
1031	Custom	0.660	VMIS	1000
1032	Custom	0.644	STAB	1100

Table 6.1.4.2 shows the five elements that have the highest utilization ratio when only the bridge landing is attached.

Table 6.1.4.2 - The five most utilized elements.

ULS-3-2, with the bridge landing only				
Beam nr	Profile	Utilization	Terms	Load
1032	Custom	0.591	STAB	1100
1056	Custom	0.581	STAB	1000
1119	Custom	0.536	VMIS	1200
1051	Custom	0.503	VMIS	1100
1034	Custom	0.487	STAB	1100

Table 6.1.4.3 shows the five elements that have the highest utilization ratio without the bridge landing and the bridge.

Table 6.1.4.3 - The five most utilized elements.

ULS-3-3, without the bridge landing and the bridge				
Beam nr	Profile	Utilization	Terms	Load
1032	Custom	0.503	STAB	1000
1012	Custom	0.451	VMIS	2000
1056	Custom	0.407	STAB	1000
1044	Custom	0.396	STAB	1200
1064	Custom	0.387	STAB	1200

Table 6.1.4.4 shows the comparison between the different ULS analysis. ULS-3-2 and ULS-3-3 will be compared to ULS-3-1 and the green color will show which ratio is the highest. The gray color shows the beam that is not included in the five highest utilization ratios.

Table 6.1.4.4 - Comparison of the five most utilized elements.

ULS ANALYSIS 2b		**ULS-3-1, with bridge landing and bridge**		**ULS-3-2, with the bridge landing only**		**ULS-3-3, without the bridge landing and the bidge**	
Beam nr	Profile	Utilization ratio	Load	Utilization ratio	Load	Utilization ratio	Load
1119	Custom	0.760	1200	0,536	1200	0,093	1200
1051	Custom	0.665	1100	0,503	1100	0,334	2000
1056	Custom	0.660	1000	0,581	1000	0,407	1000
1031	Custom	0.660	1000	0,435	1000	0,171	2100
1032	Custom	0.644	1100	0,591	1100	0,503	1000
1034	Custom	0.622	1100	0,487	1100	0,250	2000
1012	Custom	0.447	2000	0,446	2000	0,451	2000
1044	Custom	0.421	1200	0,414	1200	0,396	1200
1064	Custom	0.386	1000	0,372	1000	0,387	1200

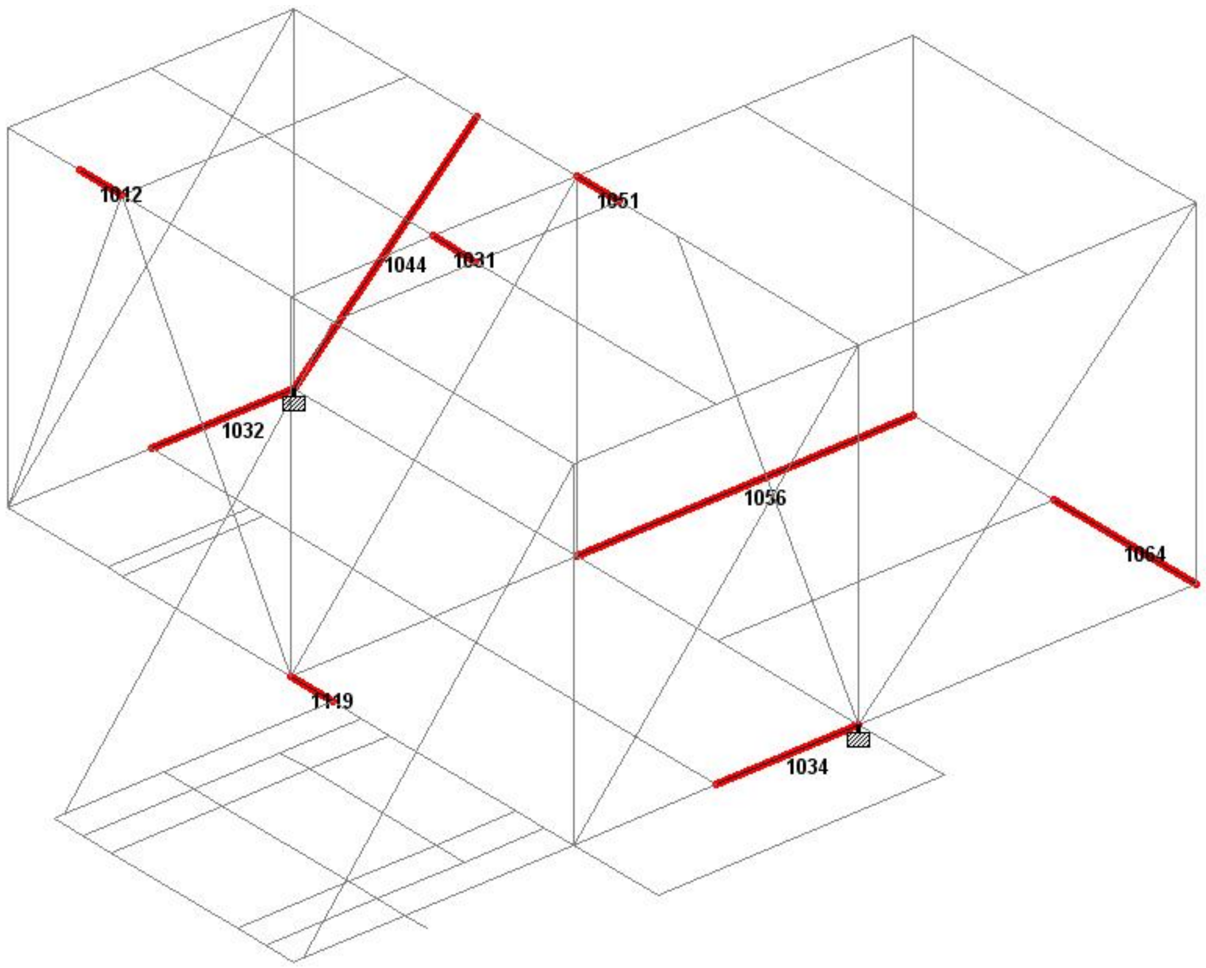


Figure 6.1.4 - The highest utilized beams in the ULS analysis for location 2b.

Table 6.1.4.5 shows the comparison between beam 1012, 1056 and 1032 with the bridge landing and the bridge attached in all of the three cases.

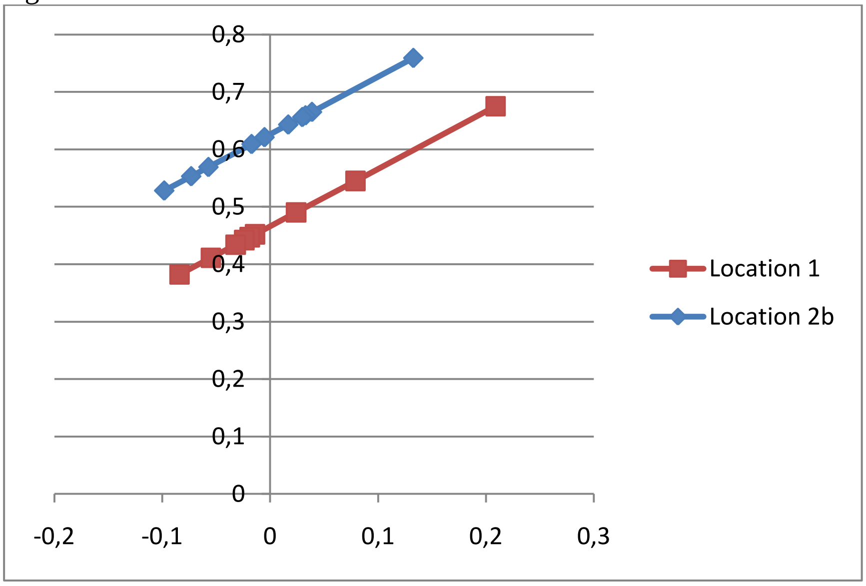
Table 6.1.4.5 - Comparison between beam 1012, 1056 and 1032.

		Location 1		**Location 2a**		**Location 2b**	
Beam nr	Profile	Utilization ratio	Load	Utilization ratio	Load	Utilization ratio	Load
1012	Custom	0,545	2000	0,461	2100	0,447	2000
1056	Custom	0,490	1000	0,674	1000	0,660	1000
1032	Custom	0,447	1100	0,641	1100	0,644	1100

6.1.5. Utilization factor variation

Figure 6.1.5 shows a presentation of the ten highest utilized beam elements and how much the utilization factor varies. The vertical axis (Y) represents the average of the ten highest utilization factors where the average is situated at X=0. The horizontal axis (X) represents how much the utilization factors differ from the average. Location 2a not has been taken account for in this presentation.

Figure 6.1.5 – Variation of the utilization factors.



6.2.SLS Results

The structure is checked for two conditions, one condition where the bridge landing is not attached and one condition where the bridge landing and the bridge itself is attached.

In both conditions, all of the beams are assumed and considered to be cantilever beams, and according to the requirements of NORSOK N-001, the maximum deflection for a cantilever beam is 2L/250 (Table 2 – Limiting values for vertical deflections).

By judging the results from the ULS analysis, Location 2a has two failed beams. Therefore, a SLS analysis of Location 2a is not done, only for Location 2b.

6.2.1. Nodal displacement, Location 1

The beams between the fixed support and node 5, 6 and 7, (See figure 6.2.1.1 and 6.2.1.2) will be checked for displacement in y-direction. The beams between the fixed support and node 205, 7 and 207, are considered to be vertical beams and will be checked for displacement in the z-direction.

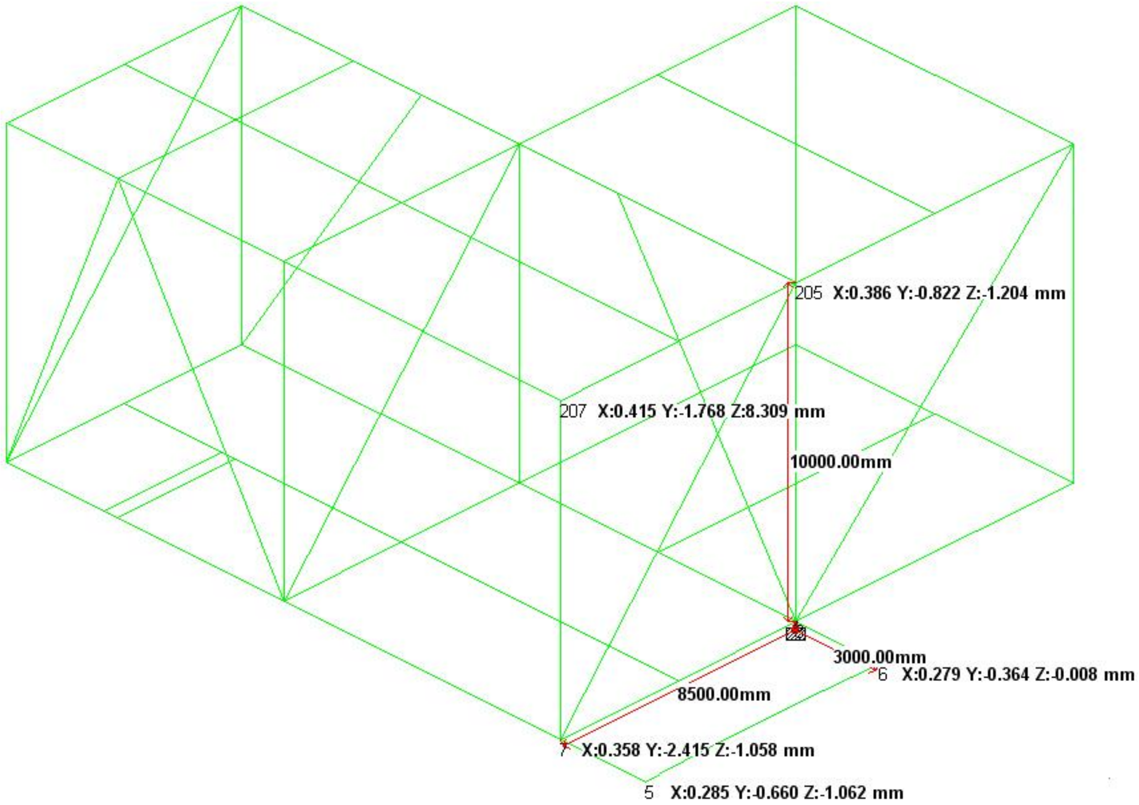


Figure 6.2.1.1 - Displacement in all directions in node 5, 6, 7, 205 and 207 without the bridge landing and the bridge attached.

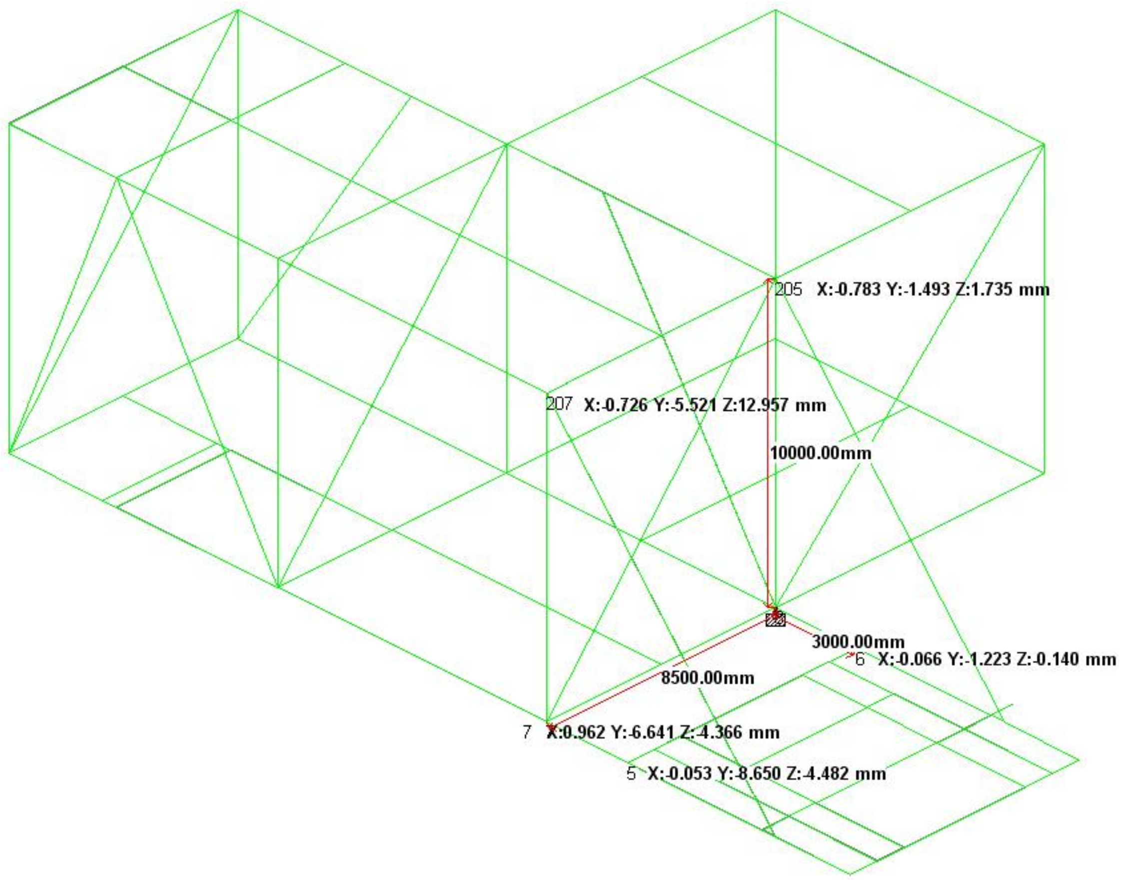


Figure 6.2.1.2- Displacements in all directions in node 5, 6, 7, 205 and 207 with the bridge landing and the bridge attached.

Table 6.2.1.1 shows the nodal displacement before installation of the bridge landing and the bridge.

Table 6.2.1.1 - Nodal displacement.

Nodal displacement before installation of the bridge landing and the bridge					
Node	5	6	7	205	207
Load	1200	1200	1200	2100	2000
Maximum displacement	0,660mm	0,364mm	2,415mm	1,204mm	8,309mm
Length of beam	3000mm	3000mm	8500mm	10000mm	10000mm
Requirements for maximum deflection in beam, 2L/250	24mm	24mm	68mm	80mm	80mm

Table 6.2.1.2 shows the nodal displacement after installation of the bridge landing and the bridge.

Table 6.2.1.2 - Nodal displacement.

Nodal displacement after installation of the bridge landing and the bridge					
Node	5	6	7	205	207
Load	1200	1200	1200	2000	2000
Maximum displacement	8,650mm	1,223mm	6,641mm	1,735mm	12,957mm
Length of beam	3000mm	3000mm	8500mm	10000mm	10000mm
Requirements for maximum deflection in beam, 2L/250	24mm	24mm	68mm	80mm	80mm

Table 6.2.1.3 shows a summary and the difference in nodal displacements before and after installation of the bridge landing and the bridge.

Table 6.2.1.3 - Summary of nodal displacements.

Summary of nodal displacements for location 1					
Node	5	6	7	205	207
Before the installation of the bridge landing and the bridge.	0,660mm	0,364mm	2,415mm	1,204mm	8,309mm
After the installation of the bridge landing and the bridge.	8,650mm	1,223mm	6,641mm	1,735mm	12,957mm
Difference in mm	7,990mm	0,859mm	4,226mm	0,531mm	4,648mm
Difference in %	1210,6%	236,0%	175,0%	44,1%	55,9%

6.2.2. Nodal displacement, Location 2b

Every beam will be checked for nodal displacement in y-direction.

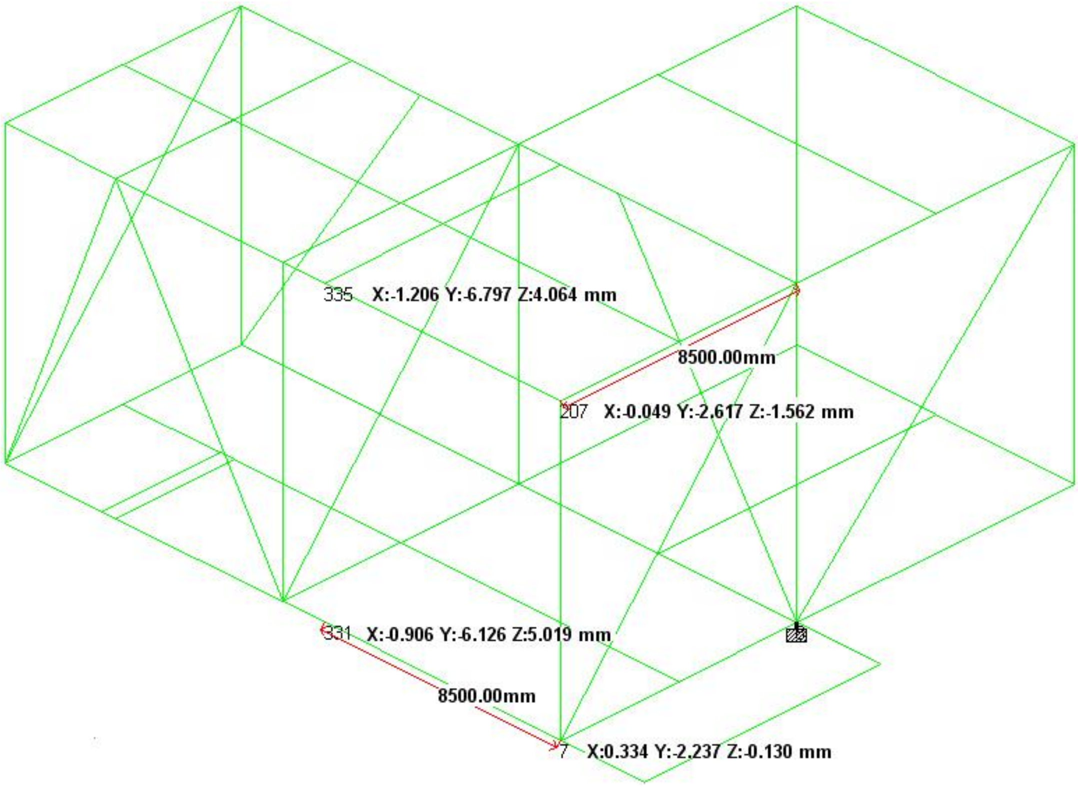


Figure 6.2.2.1 – Displacements in all directions in node 7, 207, 331 and 335 without the bridge landing and the bridge attached.

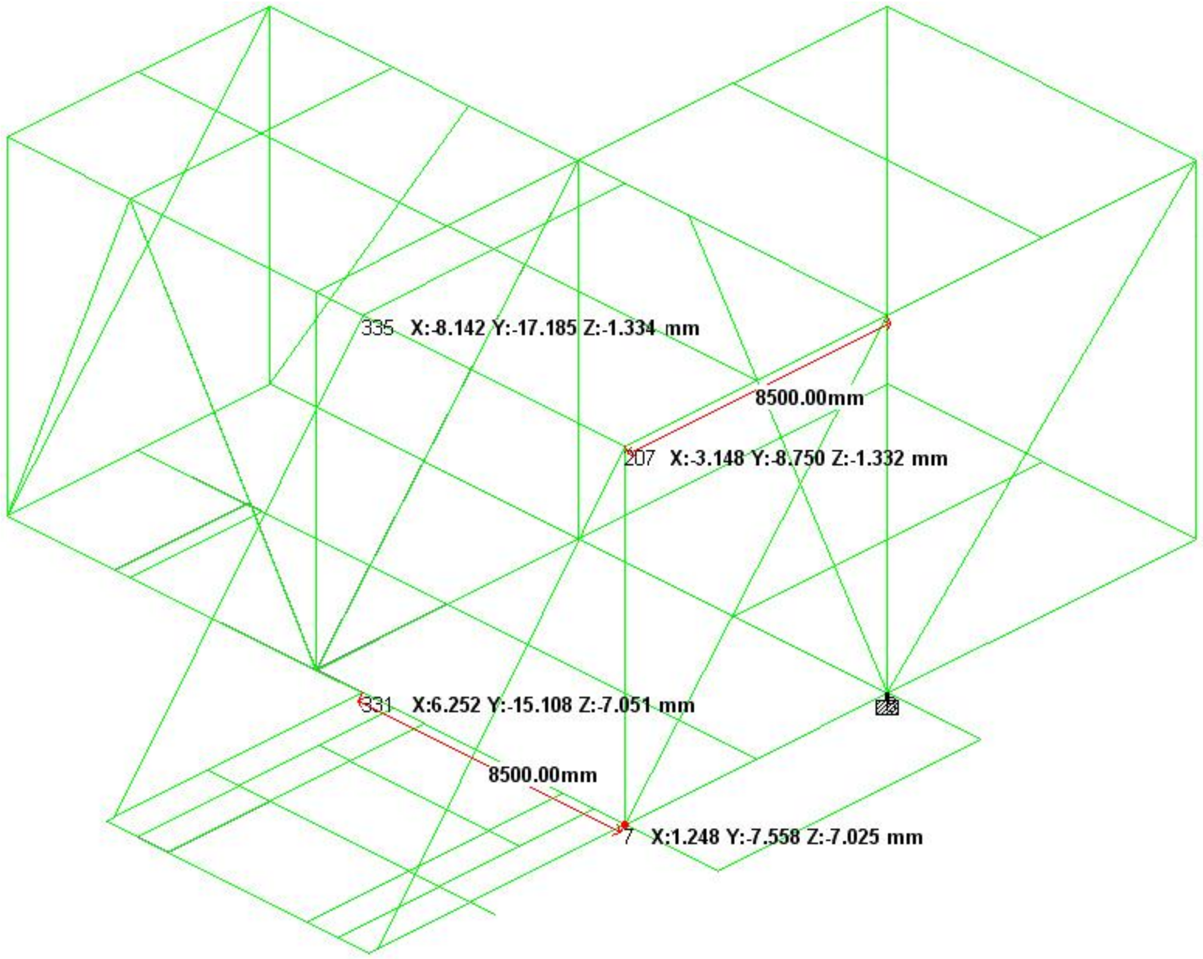


Figure 6.2.2.2 - Displacement in all directions in node 7, 207, 331 and 331 with the bridge landing and the bridge attached.

Table 6.2.2.1 shows the nodal displacement before installation of the bridge landing and the bridge.

Table 6.2.2.1 - Nodal displacement.

Nodal displacement before installation of the bridge landing and the bridge				
Node	7	207	331	335
Load	1200	1200	1200	1200
Maximum displacement	2,237mm	2,617mm	6,126mm	6,797mm
Length of beam	8500mm	8500mm	8500mm	8500mm
Requirements for maximum deflection in beam, 2L/250	68mm	68mm	68mm	68mm

Table 6.2.2.2 shows the nodal displacement after installation of the bridge landing and the bridge.

Table 6.2.2.2 - Nodal displacement.

Nodal displacement after installation of the bridge landing and the bridge				
Node	7	207	331	335
Load	1200	1200	1000	1000
Maximum displacement	7,558mm	8,750mm	15,108mm	17,185mm
Length of beam	8500mm	8500mm	8500mm	8500mm
Requirements for maximum deflection in beam, 2L/250	68mm	68mm	68mm	68mm

Table 6.2.2.3 shows a summary and the difference in nodal displacements before and after installation of the bridge landing and the bridge.

Table 6.2.2.3 – Summary of nodal displacements.

Summary of nodal displacements for location 2b				
Node	7	207	331	335
Before the installation of the bridge landing and the bridge.	2,237mm	2,617mm	6,126mm	6,797mm
After the installation of the bridge landing and the bridge.	7,558mm	8,750mm	15,108mm	17,185mm
Difference in mm	5,321mm	6,133mm	8,982mm	10,388mm
Difference in %	237,9%	234,5%	146,6%	152,8%

7. CONCLUSION

From the results in chapter 6, the ULS results, for location 1 and 2b, the capacity is high enough to withstand the forces they are subjected to. For Location 2a, beam 1014 and 1117 (See figure 6.1.3.2) has an utilization factor higher than 1. Therefore, this location will not be approved and will not be considered as an option when considering another location for the bridge landing.

All of the displacements checked in the SLS analysis are well within the requirements set by the NORSOK N-001 standard.

Considering that both the ULS and SLS analyses are approved, both of the placements of the bridge landing (location 1 and location 2b) can be considered to be real life placements. From figure 6.1.5 one can see that the ten highest utilized beam elements in location 2b are higher utilized than in location 1. The deviation from the average utilization factor is also smaller in location 2b and this means that beam elements are more evenly distributed.

Assumptions made in this thesis:

- The loads, including live loads and wind loads, affecting the platform.
- The load combinations.
- The selection and analysis of beam elements in the defined section of the platform.
- The cost of reinforcement and adding the new beam has not been considered.
- The other platform in the Draupner field has not been built and that is a factor that doesn’t contribute to selection of the placement of the bridge landing.

In terms of all the assumptions made for this thesis, and that the beam elements in location 2b have a higher and more even utilization factor than in location 1, it can be reasonable to consider placing the bridge landing in location 2b.

With other assumptions, it is possible that other conclusions may be drawn.

8. REFERENCES

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http://www.standard.no/

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Sedeniussen, Ørjan. (2007), *Bro mellom Ekofisk K(EKOK) og EkofiskB(EKOB)*, kanditatoppgave. Stavanger, Norge.

Wind data from Meteorologisk institutt by Magnar Reistad

APPENDIX

A. WIND LOADS

A.1. CHARACTERISTIC WIND VELOCITY:

Reference height:

$z_{ref} := 10m$

Cellar deck height:

$z_{cd} := 30m$

Lower main deck height:

$z_{lmd} := 38m$

Upper main deck height:

$z_{umd} := 40m$

Mezzane deck height:

$z_{md} := 45.5m$

Weather deck height:

$z_{wd} := 51m$

Reference time:

$t_0 := 3600s$

Gust wind duration:

$t := 3s$

Wind velocity at reference height:

$U_{z.ref} := 38\frac{m}{s}$

Air density:

$\rho_{air} := 1.226\frac{kg}{m^3}$

Wind angle:

$\alpha := 45$

Shape coefficient:

$C_s := 2.1$

Shape factor C:

$$C := 5.73 \cdot 10^{-2} \cdot \left(1 + 0.15 U_{z.ref} \cdot \frac{s}{m}\right)^{0.5}$$

Turbulence intensity factor I_u:

$$I_{ucd} := 0.06 \left(1 + 0.043 U_{z.ref} \cdot \frac{s}{m}\right) \cdot \left(\frac{z_{cd}}{z_{ref}}\right)^{-0.22}$$

1 hour mean wind speed U(z):

$$U_{cd}(z) := U_{z.ref} \cdot \left(1 + C \cdot \ln\left(\frac{z_{cd}}{z_{ref}}\right)\right)$$

Characteristic wind velocity u(z,t):

$$u_{cd}(z,t) := U_{cd}(z) \cdot \left(1 - 0.41 \cdot I_{ucd} \cdot \ln\left(\frac{t}{t_0}\right)\right)$$

$$u_{cd}(z,t) = 60.135 \frac{m}{s}$$

Turbulence intensity factor I_u:

$$I_{ulmd} := 0.06 \left(1 + 0.043 U_{z.ref} \cdot \frac{s}{m}\right) \cdot \left(\frac{z_{lmd}}{z_{ref}}\right)^{-0.22}$$

1 hour mean wind speed U(z):

$$U_{lmd}(z) := U_{z.ref} \cdot \left(1 + C \cdot \ln\left(\frac{z_{lmd}}{z_{ref}}\right)\right)$$

Characteristic wind velocity u(z,t):

$$u_{lmd}(z,t) := U_{lmd}(z) \cdot \left(1 - 0.41 \cdot I_{ulmd} \cdot \ln\left(\frac{t}{t_0}\right)\right)$$

$$u_{lmd}(z,t) = 61.116 \frac{m}{s}$$

Turbulence intensity factor I_u:

$$I_{uumd} := 0.06 \left(1 + 0.043 U_{z.ref} \cdot \frac{s}{m}\right) \cdot \left(\frac{z_{umd}}{z_{ref}}\right)^{-0.22}$$

1 hour mean wind speed U(z):

$$U_{umd}(z) := U_{z.ref} \cdot \left(1 + C \cdot \ln\left(\frac{z_{umd}}{z_{ref}}\right)\right)$$

Characteristic wind velocity u(z,t):

$$u_{umd}(z,t) := U_{umd}(z) \cdot \left(1 - 0.41 \cdot I_{uumd} \cdot \ln\left(\frac{t}{t_0}\right)\right)$$

$$u_{umd}(z,t) = 61.328 \frac{m}{s}$$

Turbulence intensity factor I_u:

$$I_{umd} := 0.06 \left(1 + 0.043 U_{z.ref} \cdot \frac{s}{m}\right) \cdot \left(\frac{z_{md}}{z_{ref}}\right)^{-0.22}$$

1 hour mean wind speed U(z):

$$U_{md}(z) := U_{z.ref} \cdot \left(1 + C \cdot \ln\left(\frac{z_{md}}{z_{ref}}\right)\right)$$

Characteristic wind velocity u(z,t):

$$u_{md}(z,t) := U_{md}(z) \cdot \left(1 - 0.41 \cdot I_{umd} \cdot \ln\left(\frac{t}{t_0}\right)\right)$$

$$u_{md}(z,t) = 61.859 \frac{m}{s}$$

Turbulence intensity factor I_u:

$$I_{uwd} := 0.06\left(1 + 0.043 U_{z.ref}\cdot\frac{s}{m}\right)\cdot\left(\frac{z_{wd}}{z_{ref}}\right)^{-0.22}$$

1 hour mean wind speed U(z):

$$U_{wd}(z) := U_{z.ref}\cdot\left(1 + C\cdot\ln\left(\frac{z_{wd}}{z_{ref}}\right)\right)$$

Characteristic wind velocity u(z,t):

$$u_{wd}(z,t) := U_{wd}(z)\cdot\left(1 - 0.41\cdot I_{uwd}\cdot\ln\left(\frac{t}{t_0}\right)\right)$$

$$u_{wd}(z,t) = 62.329\frac{m}{s}$$

A.2. MEAN WIND ACTION

A.2.1. WEATHER DECK:

Height of girder:

$$h_{600} := 600mm$$

Force on plate girder:

$$F_{wd600} := \frac{1}{2}\cdot\rho_{air}\cdot C_s\cdot h_{600}\cdot u_{wd}(z,t)^2\cdot\sin(\alpha)$$

$$F_{wd600} = 2.553\frac{kN}{m}$$

Height of girder:

$$h_{800} := 800mm$$

Force on plate girder:

$$F_{wd800} := \frac{1}{2}\cdot\rho_{air}\cdot C_s\cdot h_{800}\cdot u_{wd}(z,t)^2\cdot\sin(\alpha)$$

$$F_{wd800} = 3.404\frac{kN}{m}$$

A.2.2. MEZZANE DECK:

Height of girder:

$h_{400} := 400mm$

Force on plate girder:

$F_{md400} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{400} \cdot u_{md}(z,t)^2 \cdot \sin(\alpha)$

$F_{md400} = 1.677 \frac{kN}{m}$

Height of girder:

$h_{450} := 450mm$

Force on plate girder:

$F_{md450} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{450} \cdot u_{md}(z,t)^2 \cdot \sin(\alpha)$

$F_{md450} = 1.886 \frac{kN}{m}$

Height of girder:

$h_{600} := 600mm$

Force on plate girder:

$F_{md600} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{600} \cdot u_{md}(z,t)^2 \cdot \sin(\alpha)$

$F_{md600} = 2.515 \frac{kN}{m}$

Height of girder:

$h_{1000} := 1000mm$

Force on plate girder:

$F_{md1000} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{1000} \cdot u_{md}(z,t)^2 \cdot \sin(\alpha)$

$F_{md1000} = 4.192 \frac{kN}{m}$

A.2.3. UPPER MAIN DECK:

Height of girder:

$h_{340} := 340mm$

Force on plate girder:

$F_{umd340} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{340} \cdot u_{umd}(z,t)^2 \cdot \sin(\alpha)$

$F_{umd340} = 1.401 \frac{kN}{m}$

Height of girder:

$h_{400} := 400mm$

Force on plate girder:

$F_{umd400} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{400} \cdot u_{umd}(z,t)^2 \cdot \sin(\alpha)$

$F_{umd400} = 1.648 \frac{kN}{m}$

Height of girder:

$h_{800} := 800mm$

Force on plate girder:

$$F_{umd800} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{800} \cdot u_{umd}(z,t)^2 \cdot \sin(\alpha)$$

$$F_{umd800} = 3.296 \frac{kN}{m}$$

Height of girder:

$h_{1000} := 1000mm$

Force on plate girder:

$$F_{umd1000} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{1000} \cdot u_{umd}(z,t)^2 \cdot \sin(\alpha)$$

$$F_{umd1000} = 4.12 \frac{kN}{m}$$

Height of girder:

$h_{1500} := 1500mm$

Force on plate girder:

$$F_{umd1500} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{1500} \cdot u_{umd}(z,t)^2 \cdot \sin(\alpha)$$

$$F_{umd1500} = 6.18 \frac{kN}{m}$$

A.2.4. LOWER MAIN DECK:

Height of girder:

$h_{400} := 400mm$

Force on plate girder:

$$F_{lmd400} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{400} \cdot u_{lmd}(z,t)^2 \cdot \sin(\alpha)$$

$$F_{lmd400} = 1.637 \frac{kN}{m}$$

Height of girder:

$h_{500} := 500mm$

Force on plate girder:

$$F_{lmd500} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{500} \cdot u_{lmd}(z,t)^2 \cdot \sin(\alpha)$$

$$F_{lmd500} = 2.046 \frac{kN}{m}$$

Height of girder:

$h_{800} := 800mm$

Force on plate girder:

$F_{lmd800} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{800} \cdot u_{lmd}(z,t)^2 \cdot \sin(\alpha)$

$F_{lmd800} = 3.273 \frac{kN}{m}$

Height of girder:

$h_{1000} := 1000mm$

Force on plate girder:

$F_{lmd1000} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{1000} \cdot u_{lmd}(z,t)^2 \cdot \sin(\alpha)$

$F_{lmd1000} = 4.091 \frac{kN}{m}$

A.2.5.CELLAR DECK:

Height of girder:

$h_{500} := 500mm$

Force on plate girder:

$F_{cd500} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{500} \cdot u_{cd}(z,t)^2 \cdot \sin(\alpha)$

$F_{cd500} = 1.981 \frac{kN}{m}$

Height of girder:

$h_{600} := 600mm$

Force on plate girder:

$F_{cd600} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{600} \cdot u_{cd}(z,t)^2 \cdot \sin(\alpha)$

$F_{cd600} = 2.377 \frac{kN}{m}$

Height of girder:

$h_{700} := 700mm$

Force on plate girder:

$F_{cd700} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{700} \cdot u_{cd}(z,t)^2 \cdot \sin(\alpha)$

$F_{cd700} = 2.773 \frac{kN}{m}$

Height of girder:

$h_{800} := 800mm$

Force on plate girder:

$F_{cd800} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{800} \cdot u_{cd}(z,t)^2 \cdot \sin(\alpha)$

$F_{cd800} = 3.169 \frac{kN}{m}$

Height of girder:

$h_{1000} := 1000\,mm$

Force on plate girder:

$$F_{cd1000} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{1000} \cdot u_{cd}(z,t)^2 \cdot \sin(\alpha)$$

$$F_{cd1000} = 3.961 \frac{kN}{m}$$

Height of girder:

$h_{1500} := 1500\,mm$

Force on plate girder:

$$F_{cd1500} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{1500} \cdot u_{cd}(z,t)^2 \cdot \sin(\alpha)$$

$$F_{cd1500} = 5.942 \frac{kN}{m}$$

Height of girder:

$h_{1800} := 1800\,mm$

Force on plate girder:

$$F_{cd1800} := \frac{1}{2} \cdot \rho_{air} \cdot C_s \cdot h_{1800} \cdot u_{cd}(z,t)^2 \cdot \sin(\alpha)$$

$$F_{cd1800} = 7.13 \frac{kN}{m}$$

B. LIVE LOADS

B.1. WEATHER DECK

Storage area:

$$q_{storage} := 15 \cdot \frac{kN}{m^2}$$

300mm Girder:

$$Q_{s300} := q_{storage} \cdot 300mm = 4.5 \frac{kN}{m}$$

500mm Girder:

$$Q_{s500} := q_{storage} \cdot 500mm = 7.5 \frac{kN}{m}$$

400mm Girder:

$$Q_{s400} := q_{storage} \cdot 400mm = 6 \cdot \frac{kN}{m}$$

Walkway area:

$$q_{walkway} := 4 \frac{kN}{m^2}$$

220mm Girder:

$$Q_{w220} := q_{walkway} \cdot 220mm = 0.88 \frac{kN}{m}$$

400mm Girder:

$$Q_{w400} := q_{walkway} \cdot 400mm = 1.6 \frac{kN}{m}$$

300mm Girder:

$$Q_{w300} := q_{walkway} \cdot 300mm = 1.2 \frac{kN}{m}$$

500mm Girder:

$$Q_{w500} := q_{walkway} \cdot 500mm = 2 \cdot \frac{kN}{m}$$

B.2. MEZZANE DECK

Storage area:

$q_{storage} := 15\cdot\frac{kN}{m^2}$

250mm Girder:

$Q_{s250} := q_{storage}\cdot 250mm = 3.75\,\frac{kN}{m}$

300mm Girder:

$Q_{s300} := q_{storage}\cdot 300mm = 4.5\,\frac{kN}{m}$

400mm Girder:

$Q_{s400} := q_{storage}\cdot 400mm = 6\cdot\frac{kN}{m}$

Laydown area:

$q_{laydown} := 15\,\frac{kN}{m^2}$

250mm Girder:

$Q_{l250} := q_{laydown}\cdot 250mm = 3.75\,\frac{kN}{m}$

300mm Girder:

$Q_{l300} := q_{laydown}\cdot 300mm = 4.5\,\frac{kN}{m}$

400mm Girder:

$Q_{l400} := q_{laydown}\cdot 400mm = 6\cdot\frac{kN}{m}$

Walkway area:

$q_{walkway} := 4\,\frac{kN}{m^2}$

220mm Girder:

$Q_{w220} := q_{walkway}\cdot 220mm = 0.88\,\frac{kN}{m}$

250mm Girder:

$Q_{w250} := q_{walkway}\cdot 250mm = 1\cdot\frac{kN}{m}$

300mm Girder:

$Q_{w300} := q_{walkway}\cdot 300mm = 1.2\,\frac{kN}{m}$

400mm Girder:

$Q_{w400} := q_{walkway}\cdot 400mm = 1.6\,\frac{kN}{m}$

B.3. UPPER MAIN DECK

Storage area:

$q_{storage} := 15 \cdot \frac{kN}{m^2}$

250mm Girder:

$Q_{s250} := q_{storage} \cdot 250mm = 3.75 \frac{kN}{m}$

300mm Girder:

$Q_{s300} := q_{storage} \cdot 300mm = 4.5 \frac{kN}{m}$

400mm Girder:

$Q_{s400} := q_{storage} \cdot 400mm = 6 \cdot \frac{kN}{m}$

600mm Girder:

$Q_{s600} := q_{storage} \cdot 600mm = 9 \cdot \frac{kN}{m}$

Area between equipment:

$q_{equipment} := 5 \cdot \frac{kN}{m^2}$

250mm Girder:

$Q_{e250} := q_{equipment} \cdot 250mm = 1.25 \frac{kN}{m}$

400mm Girder:

$Q_{e400} := q_{equipment} \cdot 400mm = 2 \cdot \frac{kN}{m}$

Laydown area:

$q_{laydown} := 15 \frac{kN}{m^2}$

250mm Girder:

$Q_{l250} := q_{laydown} \cdot 250mm = 3.75 \frac{kN}{m}$

300mm Girder:

$Q_{l300} := q_{laydown} \cdot 300mm = 4.5 \frac{kN}{m}$

400mm Girder:

$Q_{l400} := q_{laydown} \cdot 400mm = 6 \cdot \frac{kN}{m}$

Walkway area:

$q_{walkway} := 4 \frac{kN}{m^2}$

250mm Girder:

$Q_{w250} := q_{walkway} \cdot 250mm = 1 \cdot \frac{kN}{m}$

300mm Girder:

$Q_{w300} := q_{walkway} \cdot 300mm = 1.2 \frac{kN}{m}$

400mm Girder:

$Q_{w400mm} := q_{walkway} \cdot 400mm = 1.6 \frac{kN}{m}$

B.4. LOWER MAIN DECK

Storage area:

$$q_{storage} := 15 \cdot \frac{kN}{m^2}$$

250mm Girder:

$$Q_{s250} := q_{storage} \cdot 250mm = 3.75 \frac{kN}{m}$$

300mm Girder:

$$Q_{s300} := q_{storage} \cdot 300mm = 4.5 \frac{kN}{m}$$

400mm Girder:

$$Q_{s400} := q_{storage} \cdot 400mm = 6 \cdot \frac{kN}{m}$$

Walkway area:

$$q_{walkway} := 4 \frac{kN}{m^2}$$

200 Girder:

$$Q_{w200} := q_{walkway} \cdot 200mm = 0.8 \frac{kN}{m}$$

250mm Girder:

$$Q_{w250} := q_{walkway} \cdot 250mm = 1 \cdot \frac{kN}{m}$$

300mm Girder:

$$Q_{w300} := q_{walkway} \cdot 300mm = 1.2 \frac{kN}{m}$$

Area between equipment:

$$q_{equipment} := 5 \cdot \frac{kN}{m^2}$$

250mm Girder:

$$Q_{e250} := q_{equipment} \cdot 250mm = 1.25 \frac{kN}{m}$$

300mm Girder:

$$Q_{e300} := q_{equipment} \cdot 300mm = 1.5 \frac{kN}{m}$$

400mm Girder:

$$Q_{e400} := q_{equipment} \cdot 400mm = 2 \cdot \frac{kN}{m}$$

B.5. CELLAR DECK

Storage area:

$q_{storage} := 15 \cdot \frac{kN}{m^2}$

200mm Girder:

$Q_{s200} := q_{storage} \cdot 200mm = 3 \cdot \frac{kN}{m}$

300mm Girder:

$Q_{s300} := q_{storage} \cdot 300mm = 4.5 \frac{kN}{m}$

400mm Girder:

$Q_{s400} := q_{storage} \cdot 400mm = 6 \cdot \frac{kN}{m}$

500mm Girder:

$Q_{s500} := q_{storage} \cdot 500mm = 7.5 \frac{kN}{m}$

Laydown area:

$q_{laydown} := 15 \cdot \frac{kN}{m^2}$

200mm Girder:

$Q_{l200} := q_{storage} \cdot 200mm = 3 \cdot \frac{kN}{m}$

300mm Girder:

$Q_{l300} := q_{storage} \cdot 300mm = 4.5 \frac{kN}{m}$

400mm Girder:

$Q_{l400} := q_{storage} \cdot 400mm = 6 \cdot \frac{kN}{m}$

500mm Girder:

$Q_{l500} := q_{storage} \cdot 500mm = 7.5 \frac{kN}{m}$

600mm Girder:

$Q_{l600} := q_{storage} \cdot 600mm = 9 \cdot \frac{kN}{m}$

Walkway area:

$q_{walkway} := 4 \frac{kN}{m^2}$

200mm Girder:

$Q_{w200} := q_{walkway} \cdot 200mm = 0.8 \frac{kN}{m}$

220mm Girder:

$Q_{w220} := q_{walkway} \cdot 220mm = 0.88 \frac{kN}{m}$

300mm Girder:

$Q_{w300} := q_{walkway} \cdot 300mm = 1.2 \frac{kN}{m}$

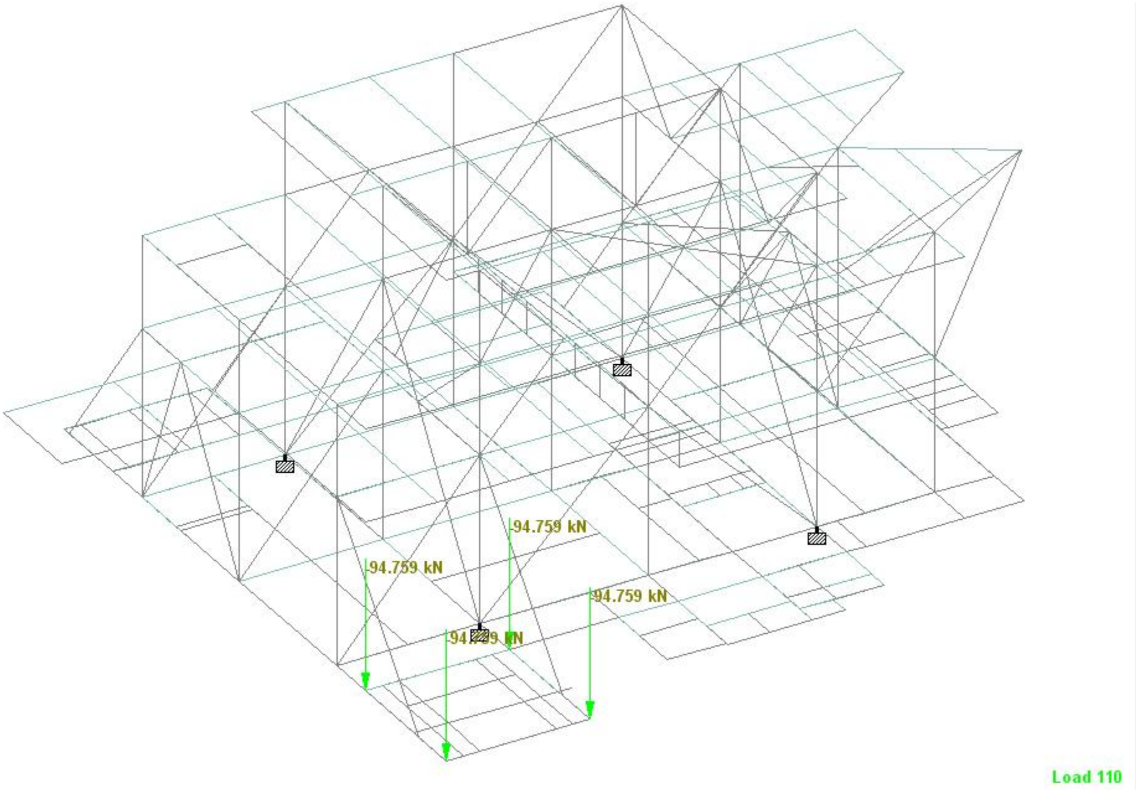
400mm Girder:

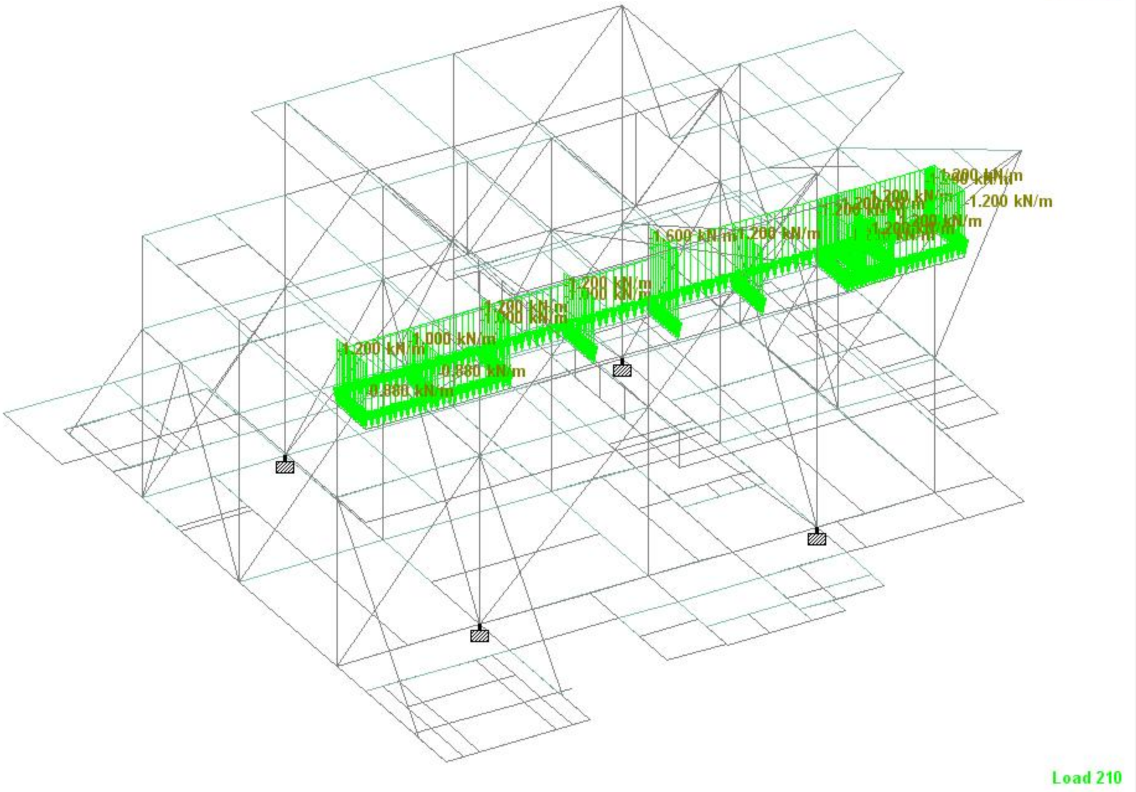
$Q_{w400} := q_{walkway} \cdot 400mm = 1.6 \frac{kN}{m}$

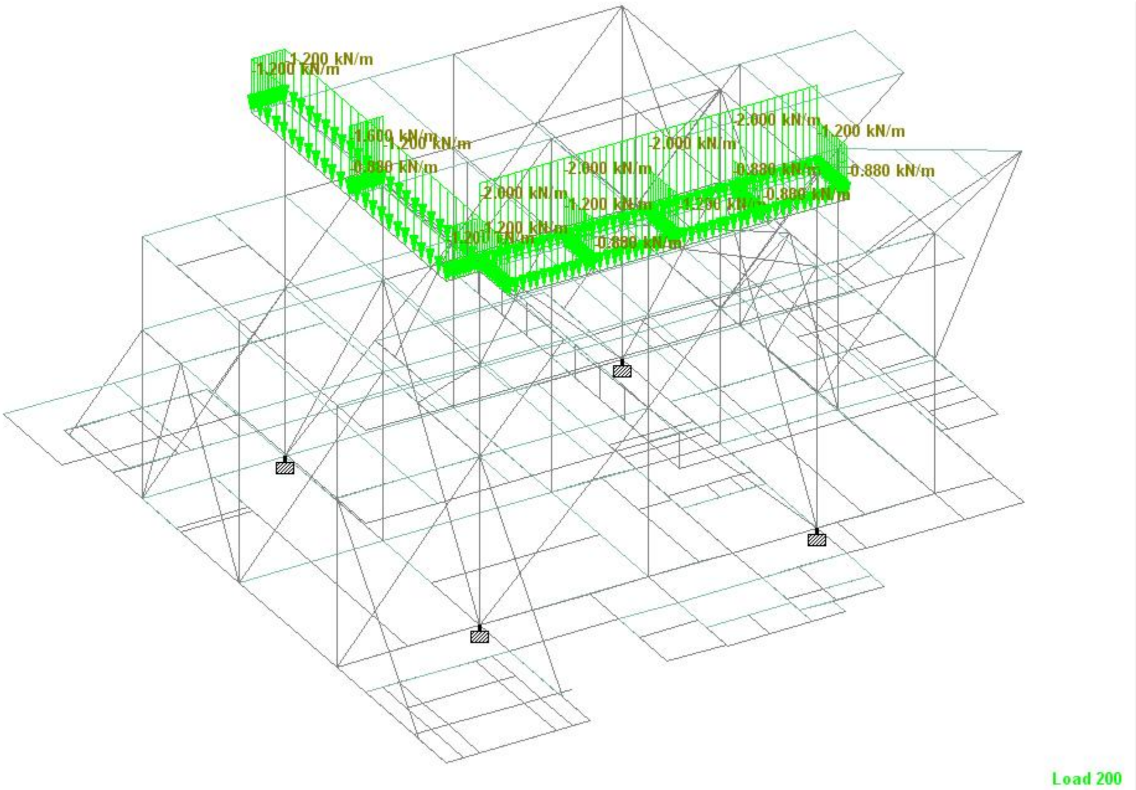
500mm Girder:

$Q_{w500} := q_{walkway} \cdot 500mm = 2 \cdot \frac{kN}{m}$

C. PICTURE OF THE LOADS



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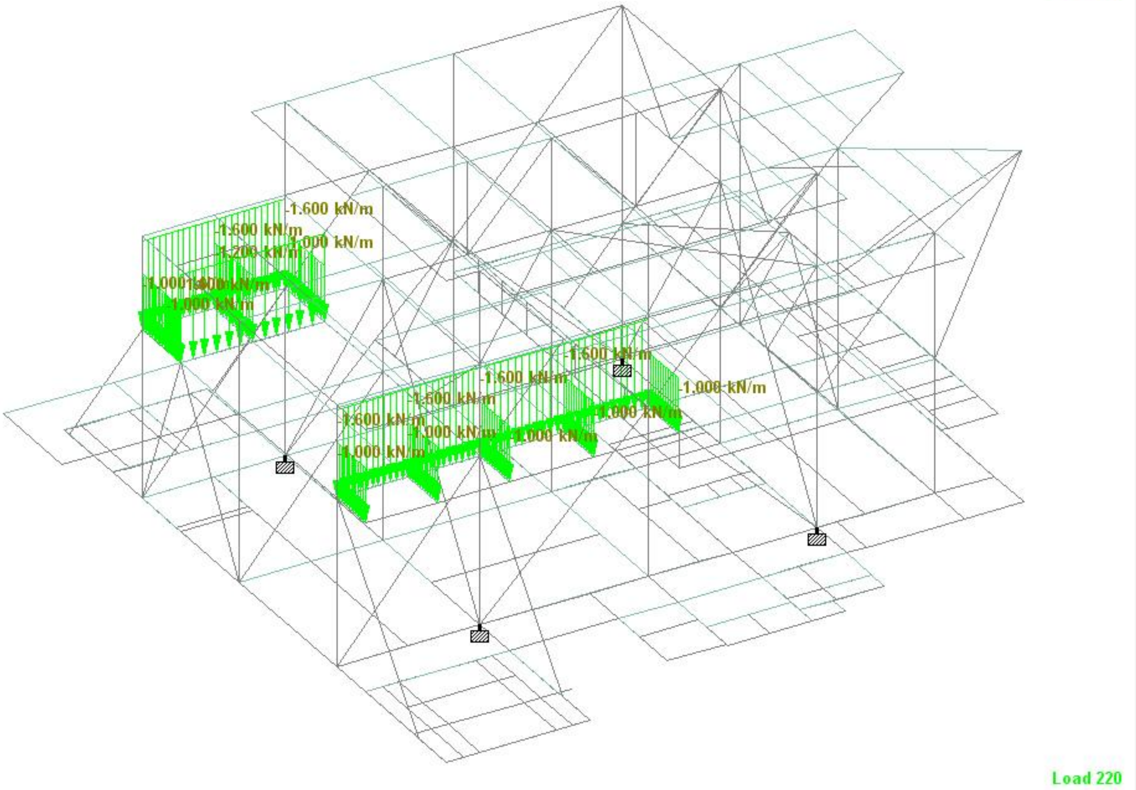
-1.200 kN/m
-1.600 kN/m
-1.200 kN/m
-0.880 kN/m
-2.000 kN/m
-2.000 kN/m
-2.000 kN/m
-2.000 kN/m
-1.200 kN/m
-1.200 kN/m
-1.200 kN/m
-0.880 kN/m
-0.880 kN/m
-0.880 kN/m
-1.200 kN/m
-0.880 kN/m
Load 200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-1.600 kN/m
-1.000 kN/m
-1.200 kN/m
-1.000 kN/m
-1.000 kN/m
-1.600 kN/m
-1.600 kN/m
-1.000 kN/m
-1.600 kN/m
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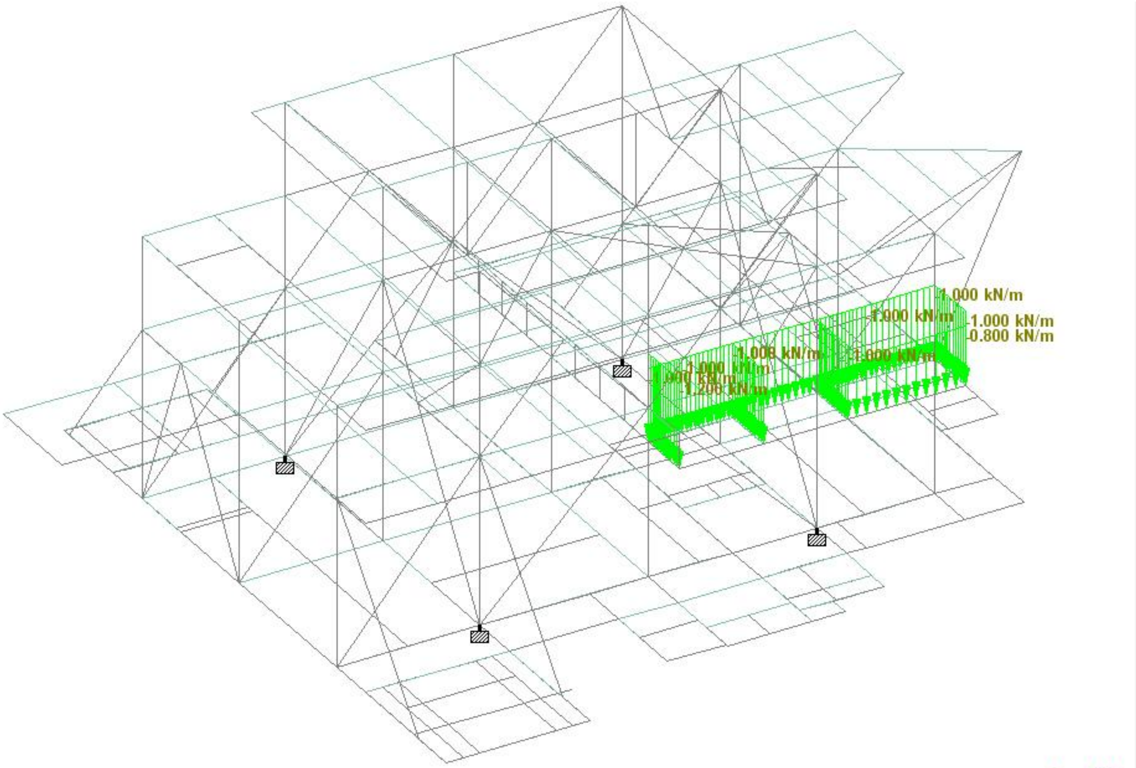
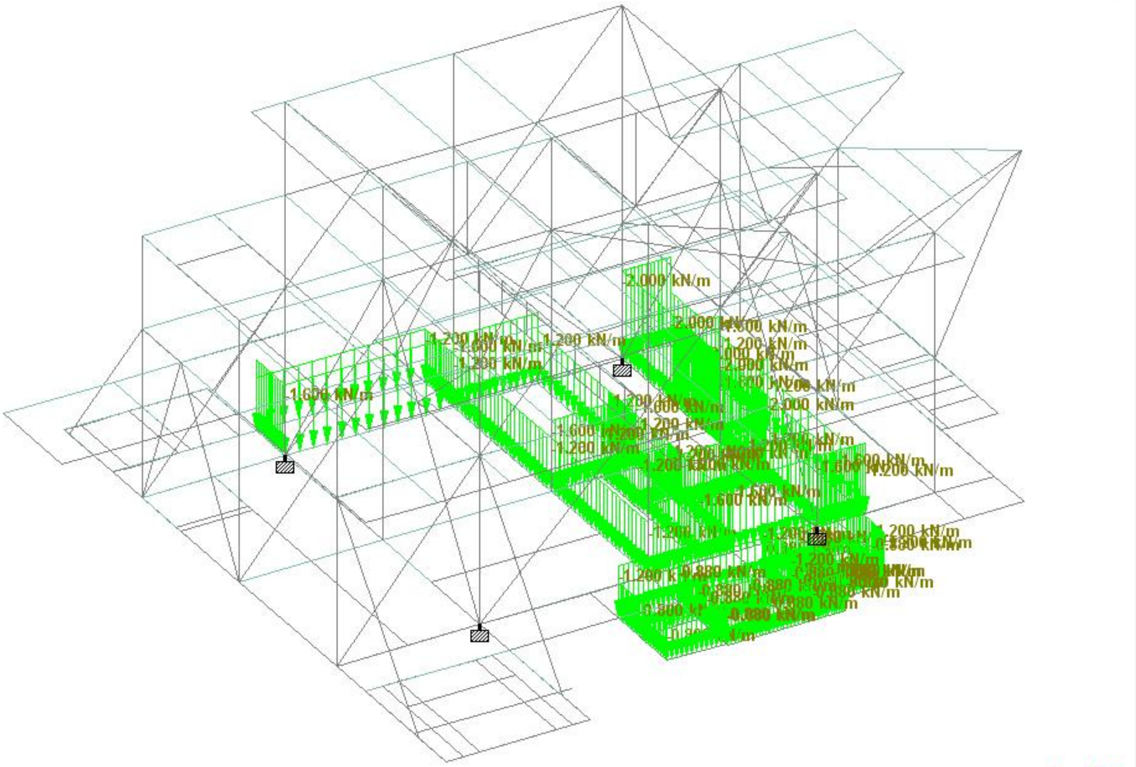
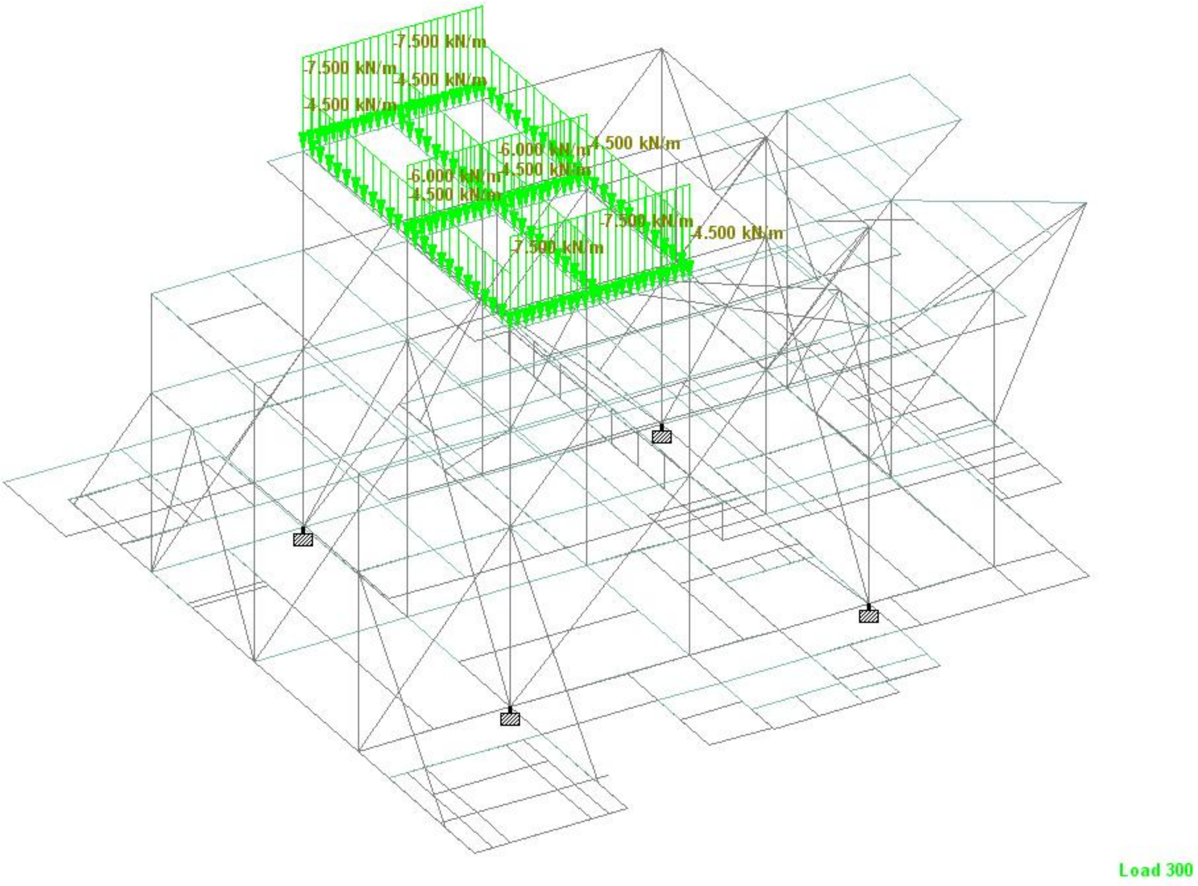
-1.000 kN/m
Load 220



Load 230



Load 240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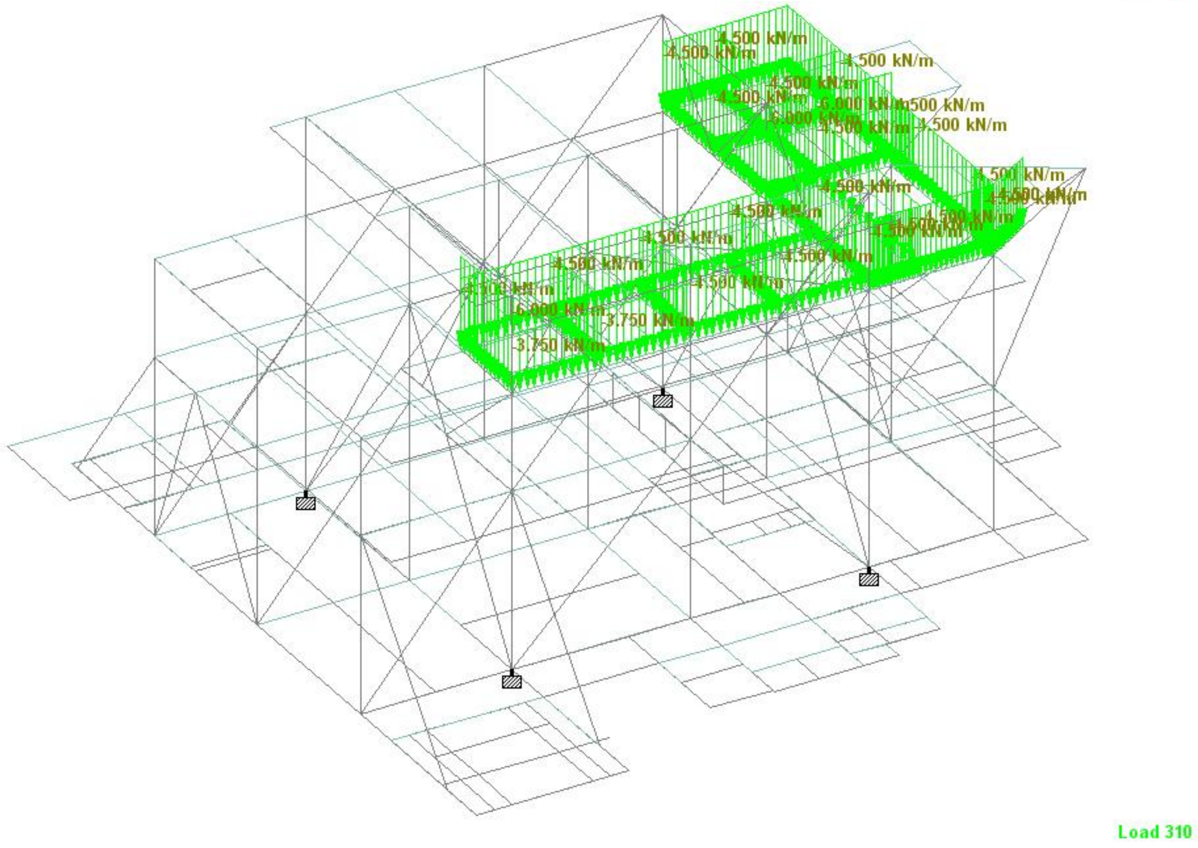
-7.500 kN/m
-4.500 kN/m
-4.500 kN/m
-6.000 kN/m
-4.500 kN/m
-6.000 kN/m
-4.500 kN/m
-4.500 kN/m
-7.500 kN/m
-4.500 kN/m
-7.500 kN/m
Load 300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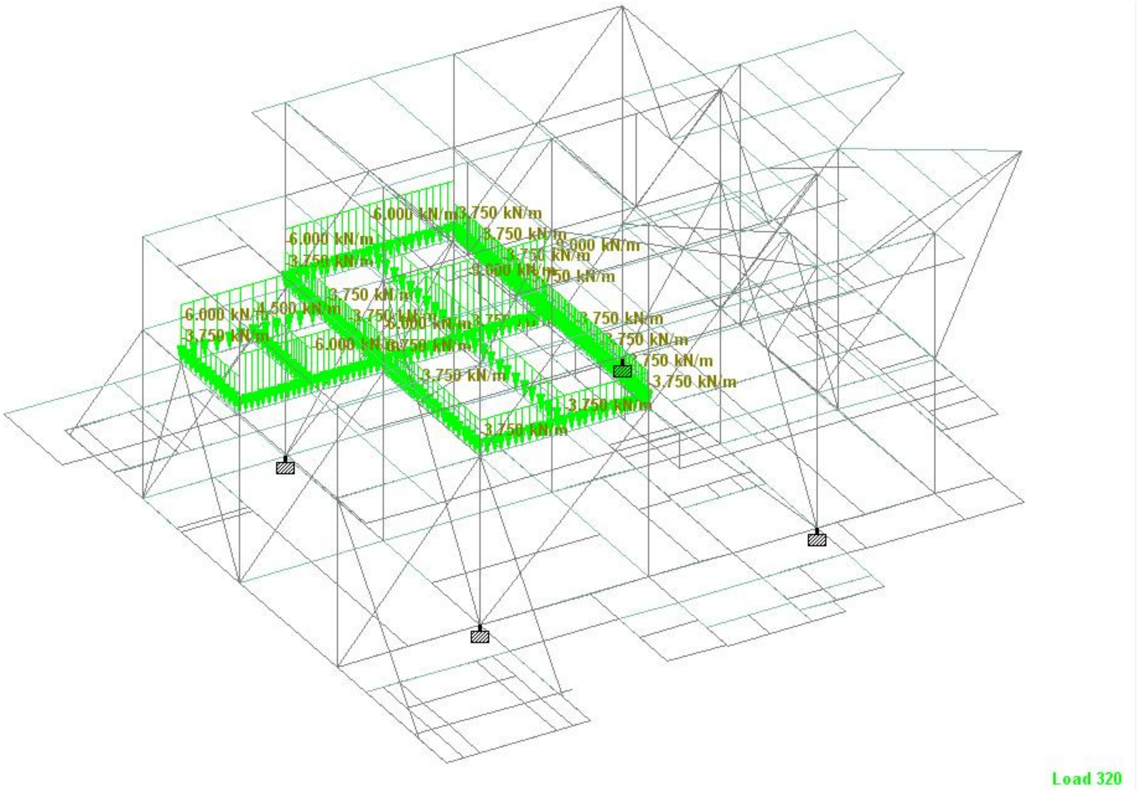
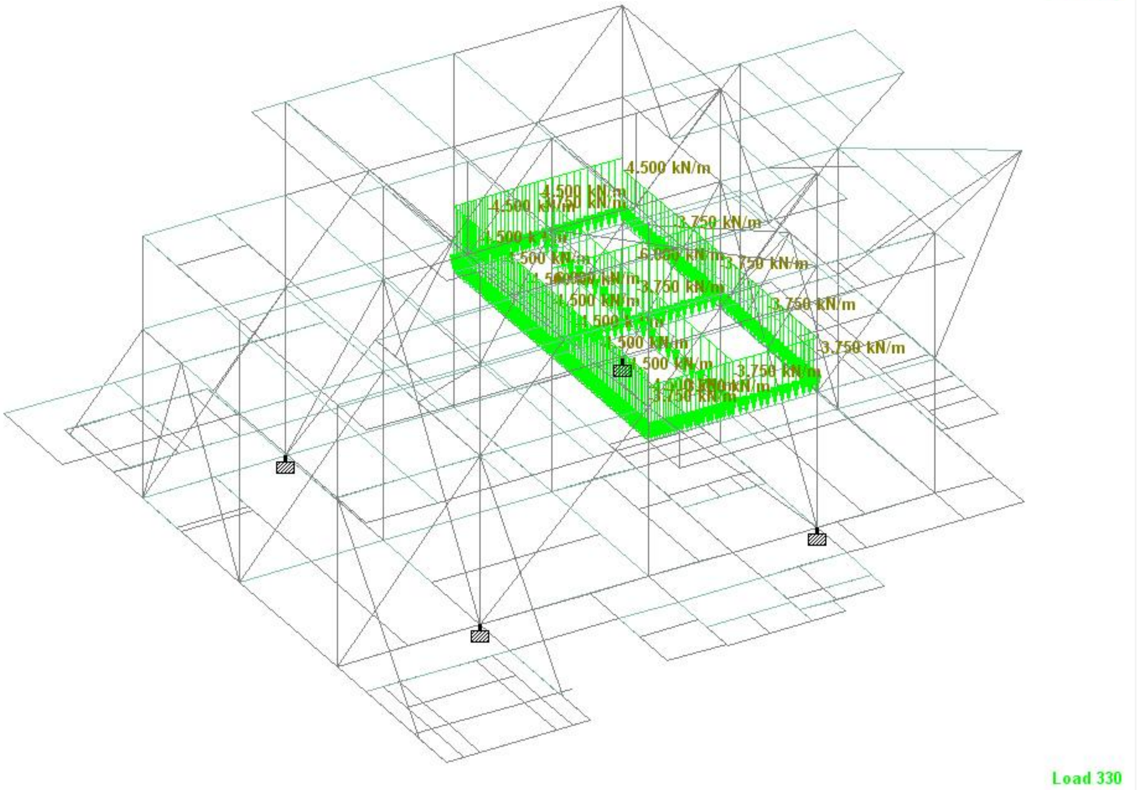
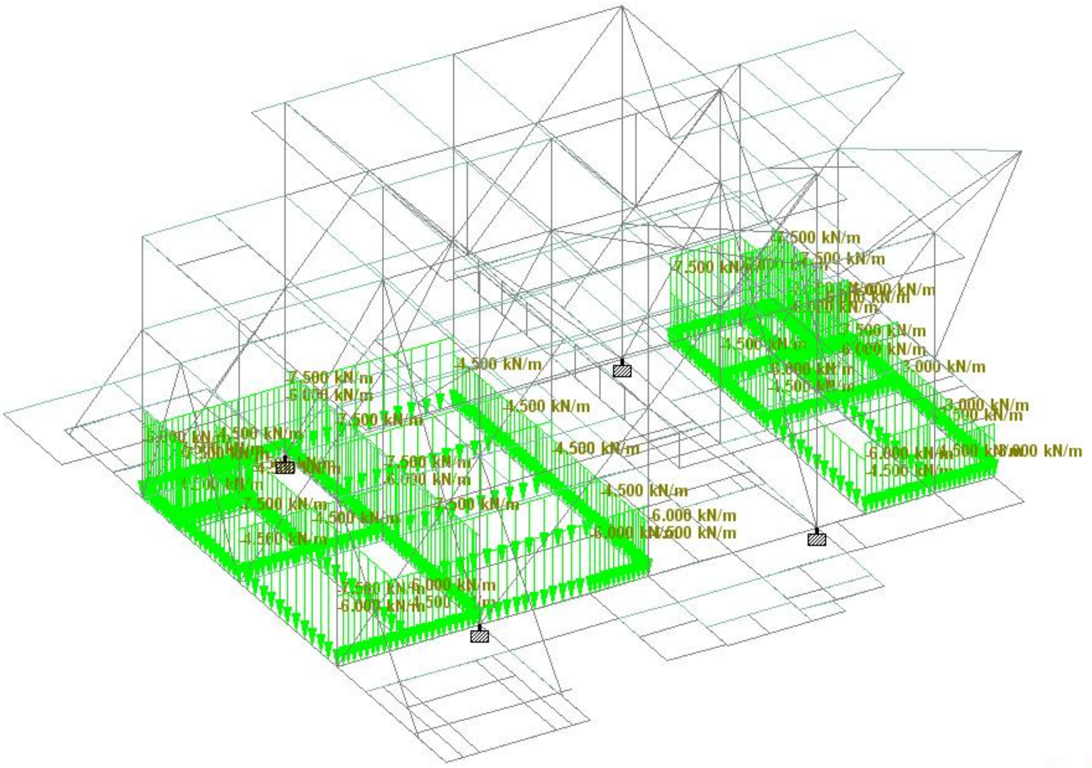
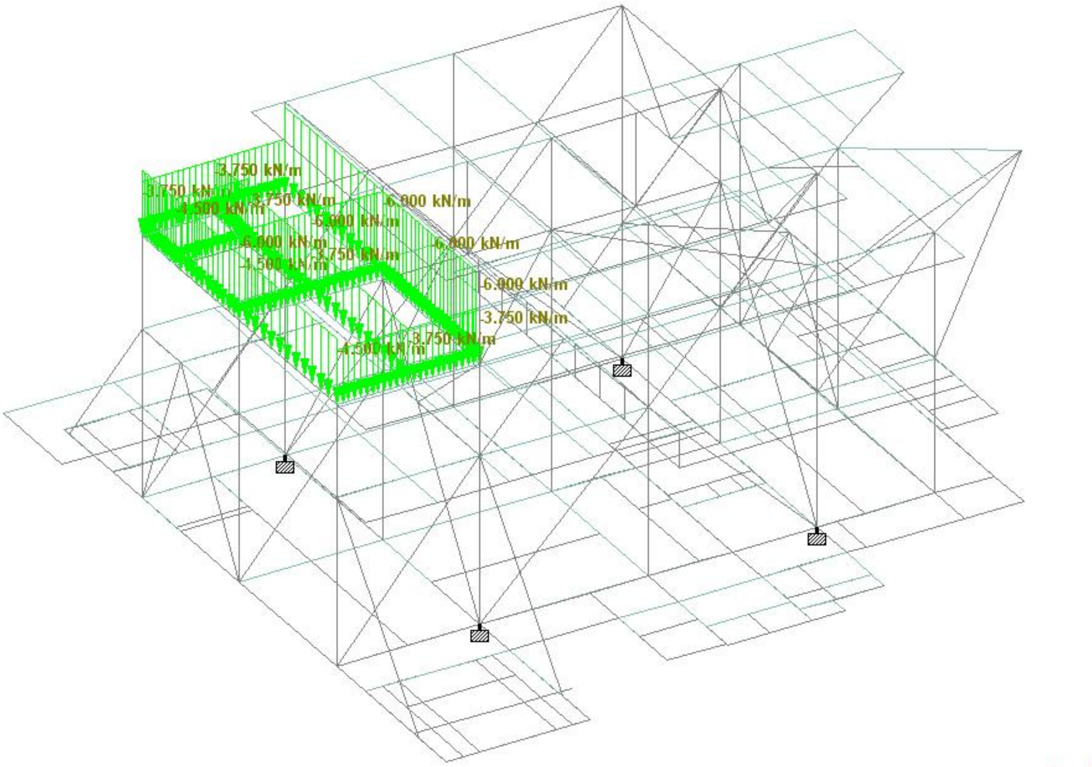
-4.500 kN/m
-4.500 kN/m
-4.500 kN/m
-6.000 kN/m
-3.750 kN/m
-3.750 kN/m
Load 310


6.000 kN/m
3.750 kN/m
6.000 kN/m
4.500 kN/m
Load 320

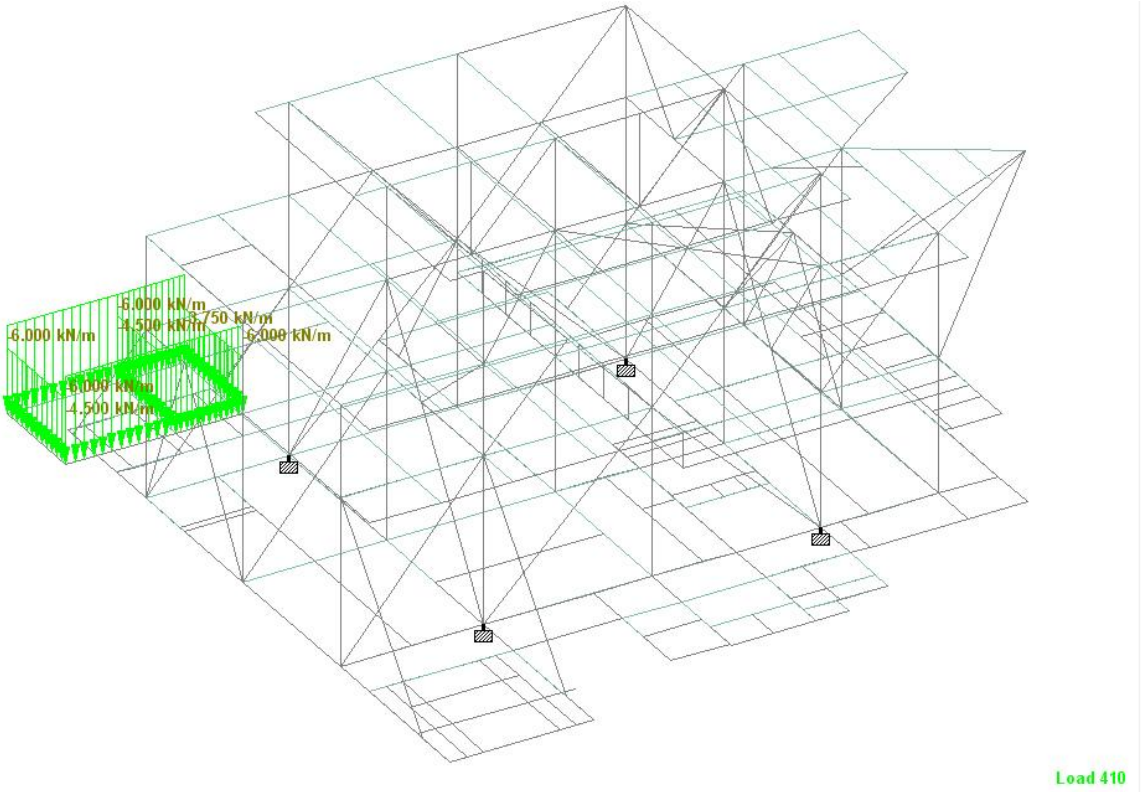

4.500 kN/m
3.750 kN/m
6.000 kN/m
Load 330



Load 340



Load 400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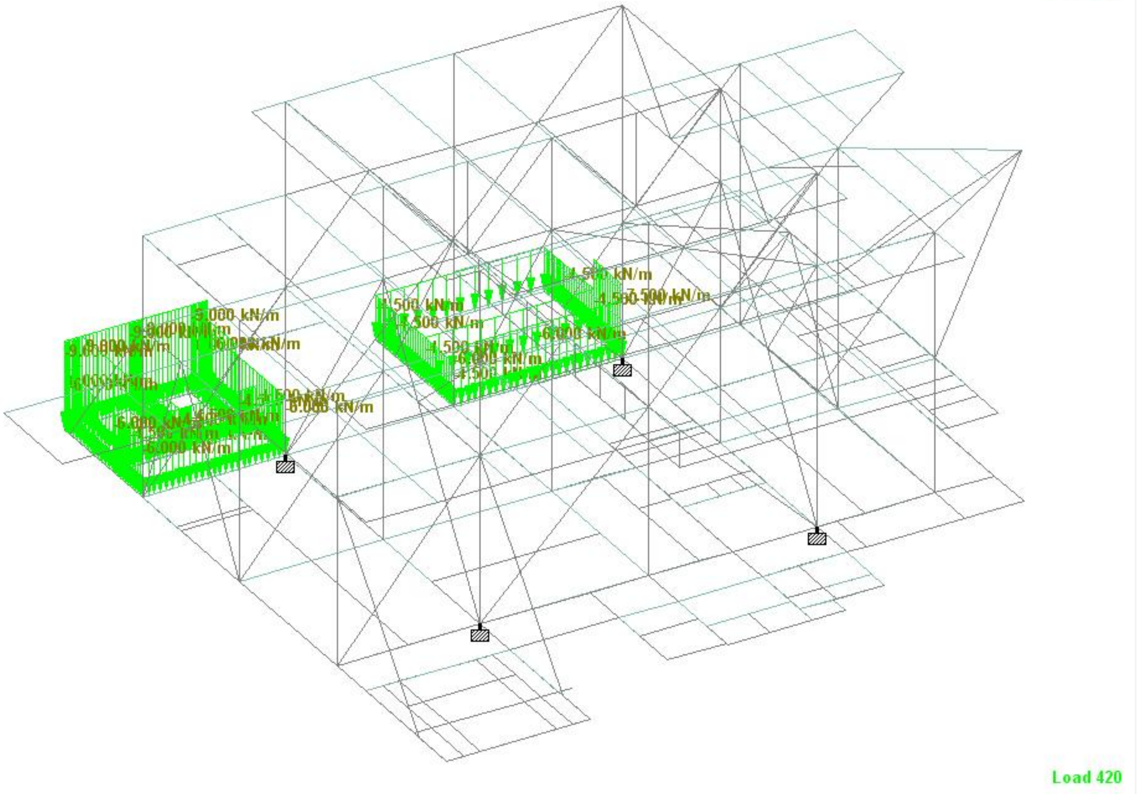
-3.750 kN/m
-6.000 kN/m
-6.000 kN/m
-6.000 kN/m
-4.500 kN/m
Load 410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-6.000 kN/m
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-4.500 kN/m
-6.000 kN/m
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-6.000 kN/m
-4.500 kN/m
-6.000 kN/m
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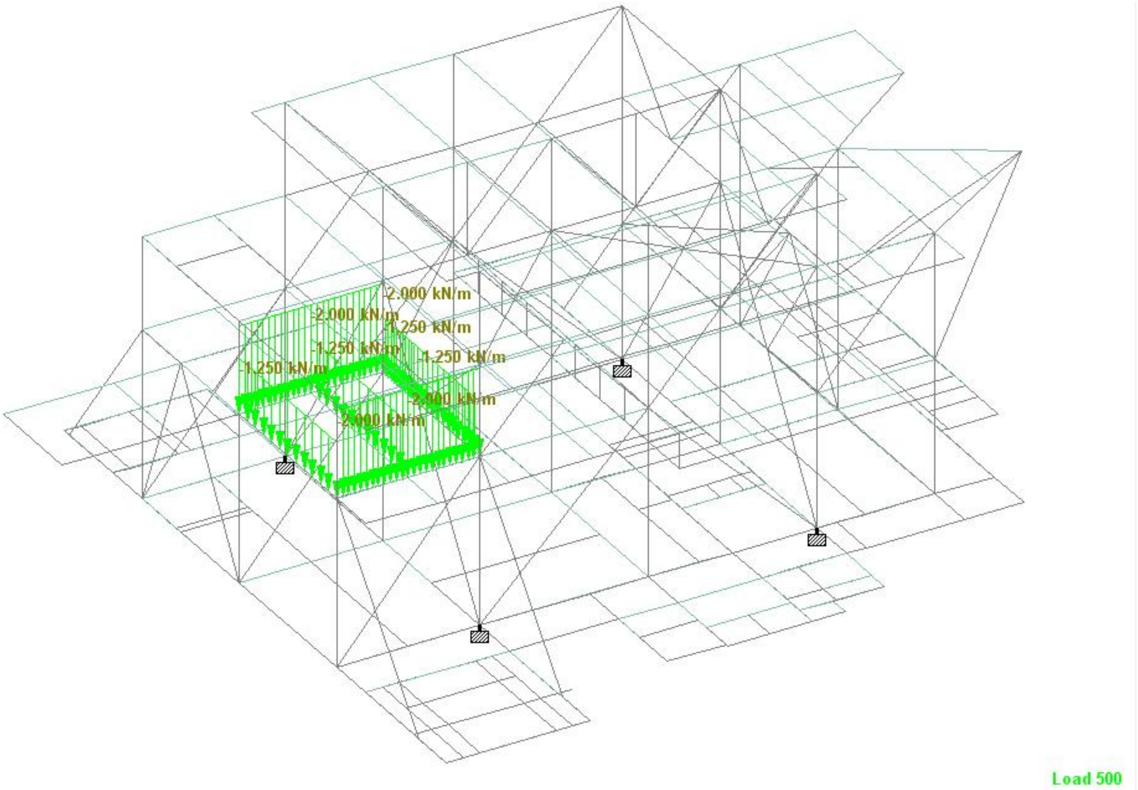
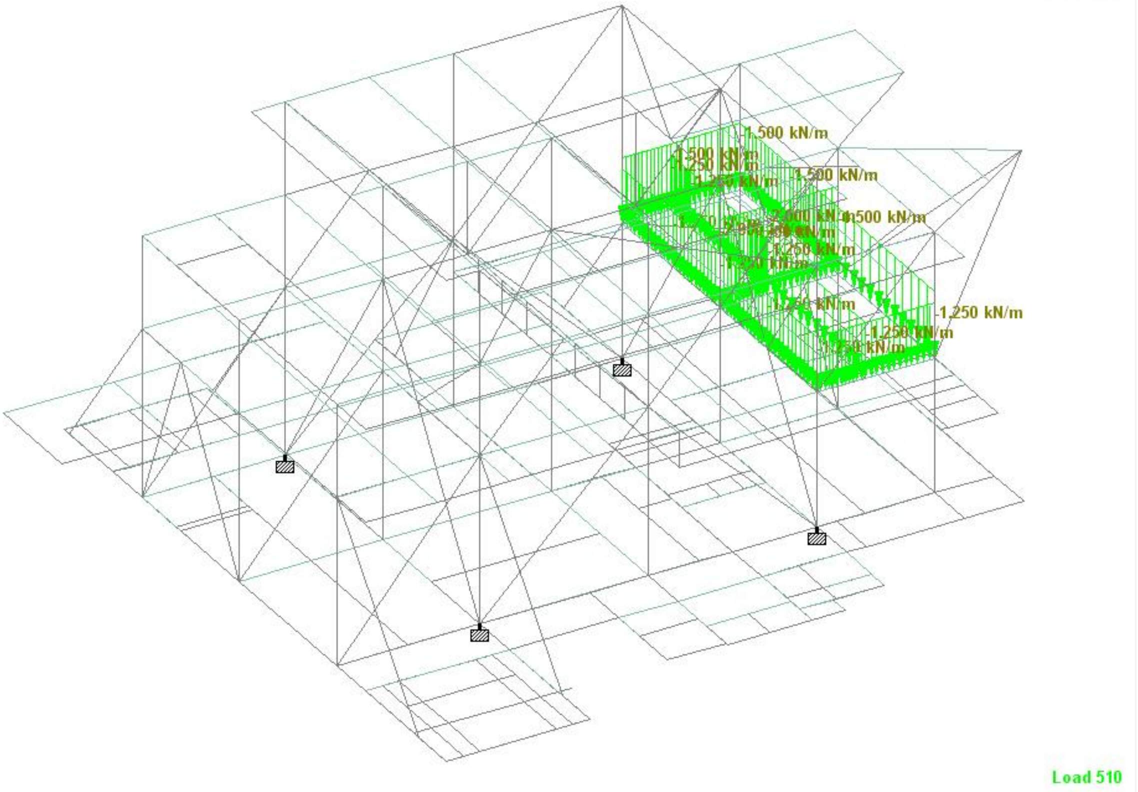
-4.500 kN/m
-6.000 kN/m
-4.500 kN/m
-6.000 kN/m
Load 420


-2,000 kN/m
-2,000 kN/m
-1,250 kN/m
-1,250 kN/m
-1,250 kN/m
-1,250 kN/m
-2,000 kN/m
-2,000 kN/m
Load 500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-1,250 kN/m
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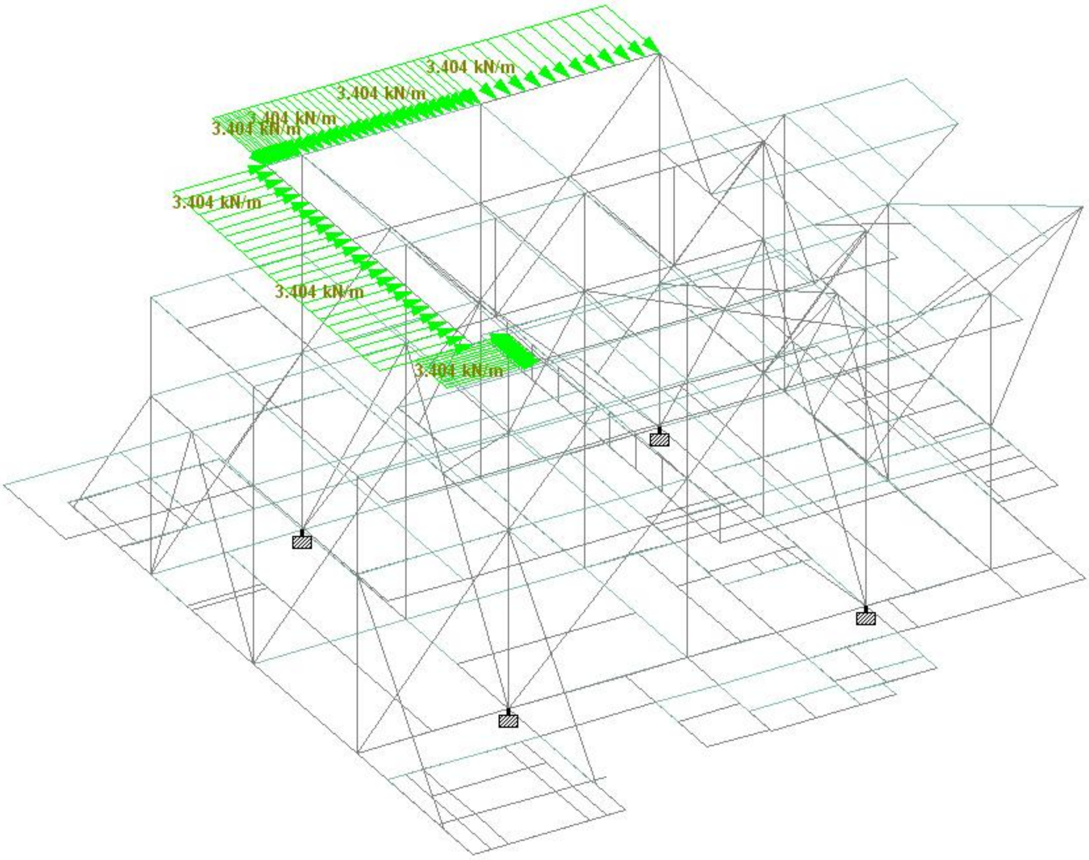
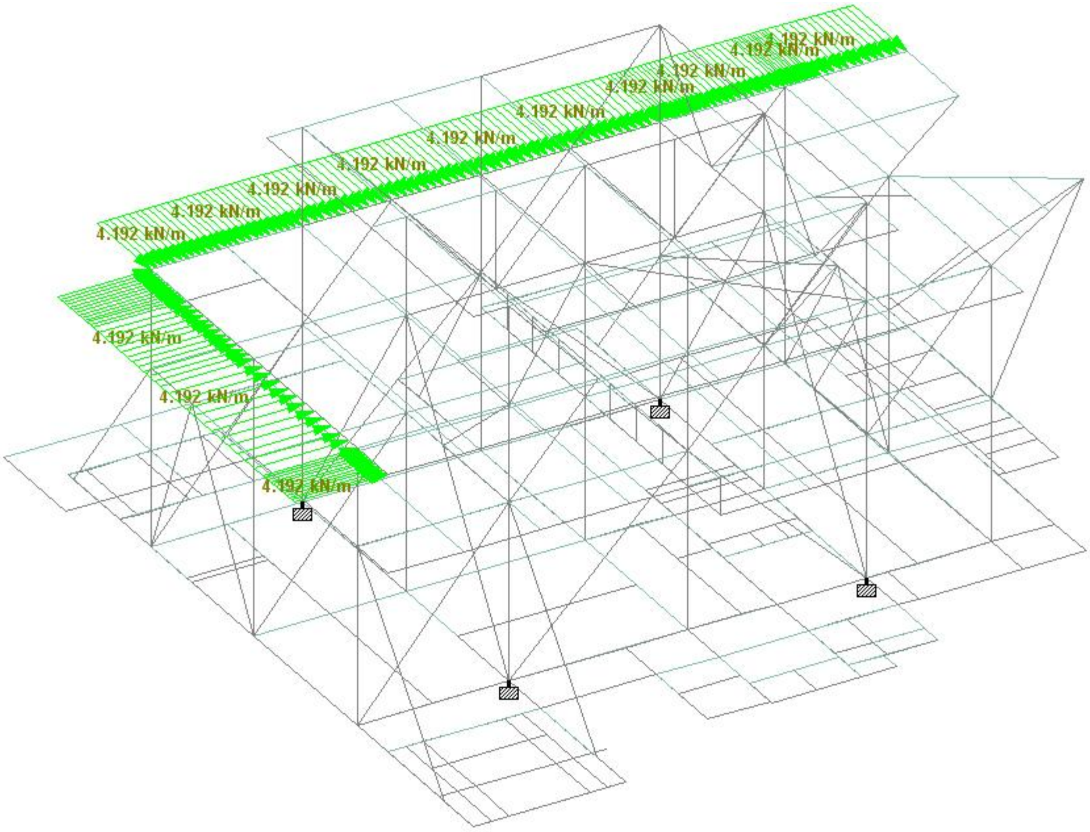
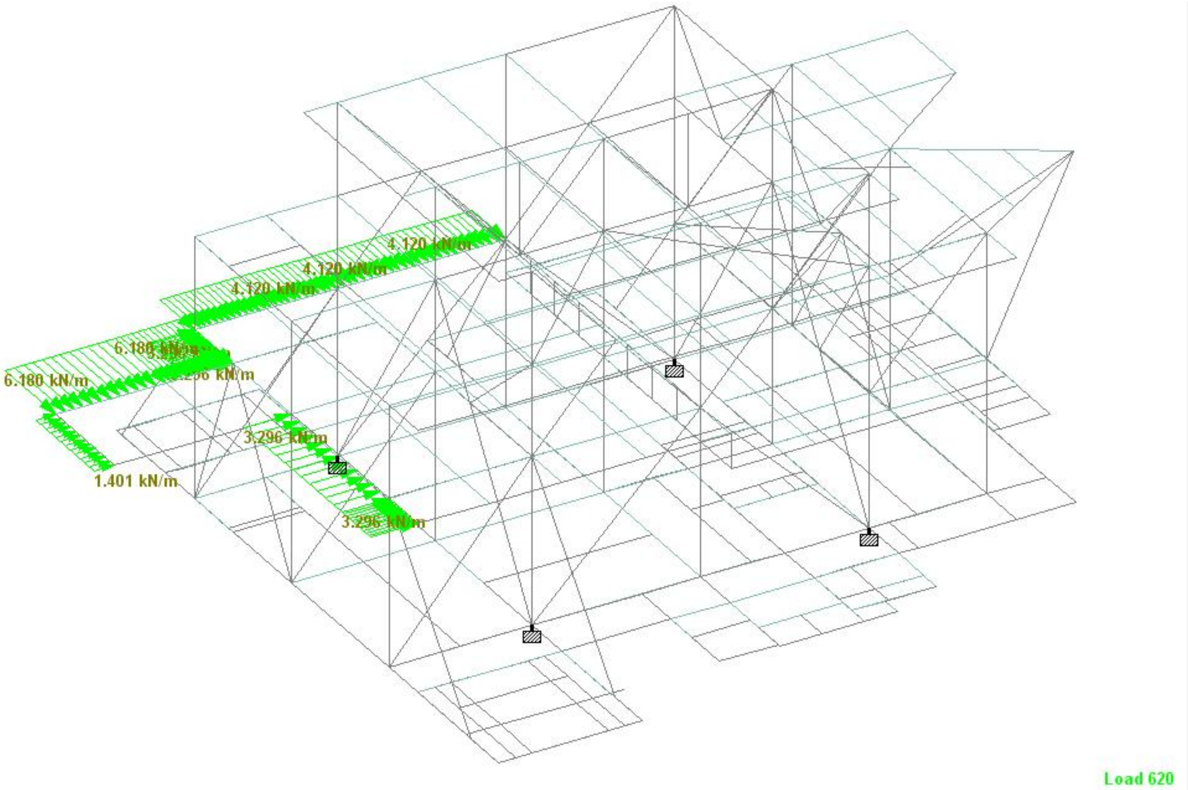
-1,250 kN/m
-1,250 kN/m
-1,250 kN/m
Load 510



Load 600



Load 610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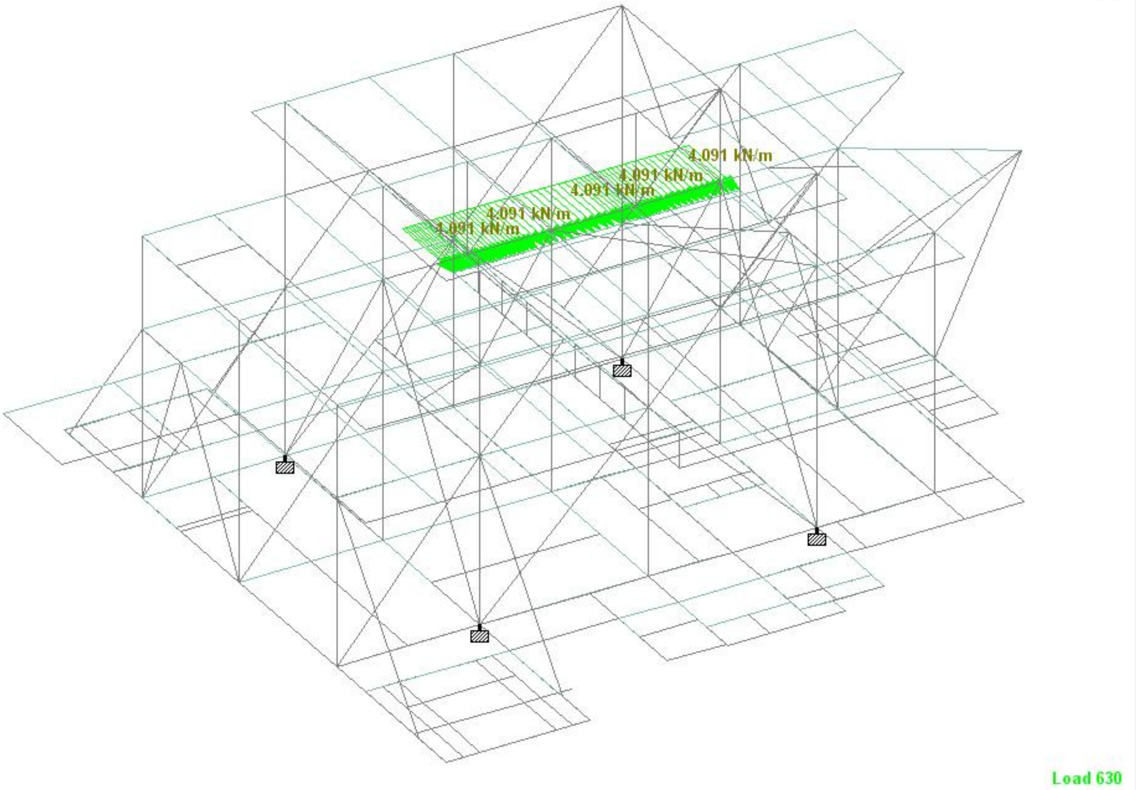
4.120 kN/m
4.120 kN/m
6.180 kN/m
6.180 kN/m
3.296 kN/m
3.296 kN/m
1.401 kN/m
3.296 kN/m
Load 620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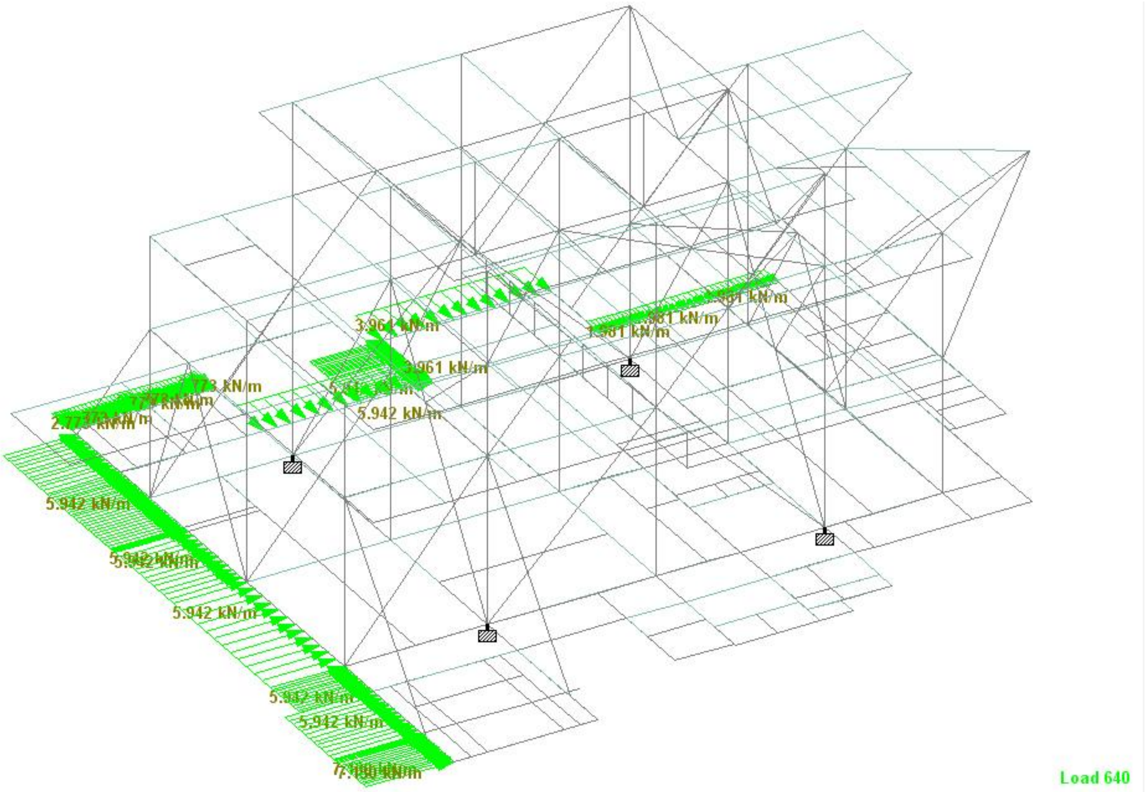
4.091 kN/m
4.091 kN/m
4.091 kN/m
4.091 kN/m
Load 630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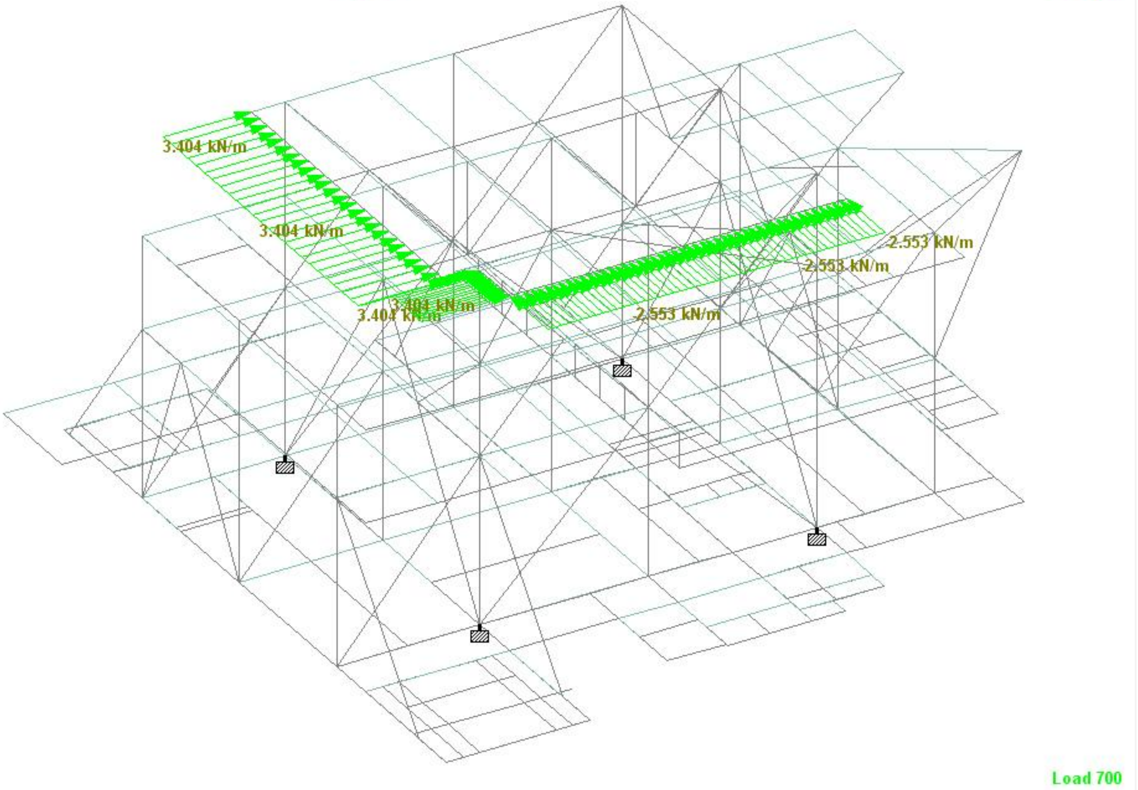
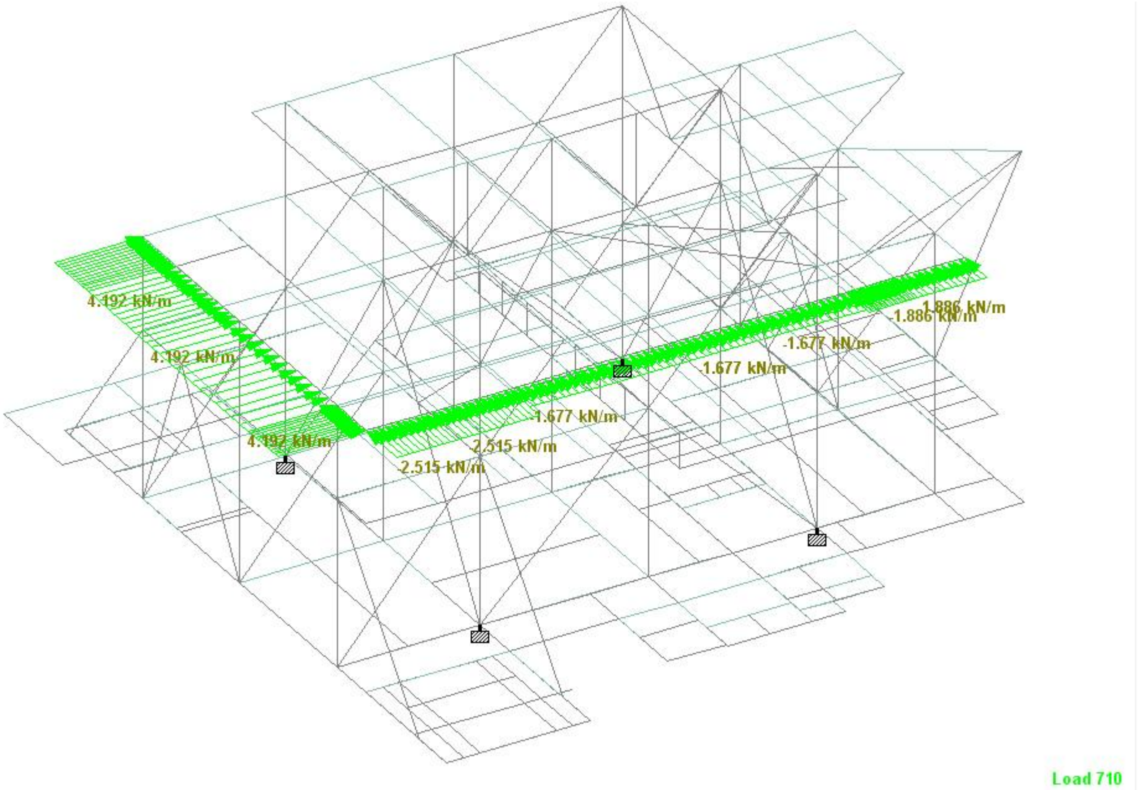
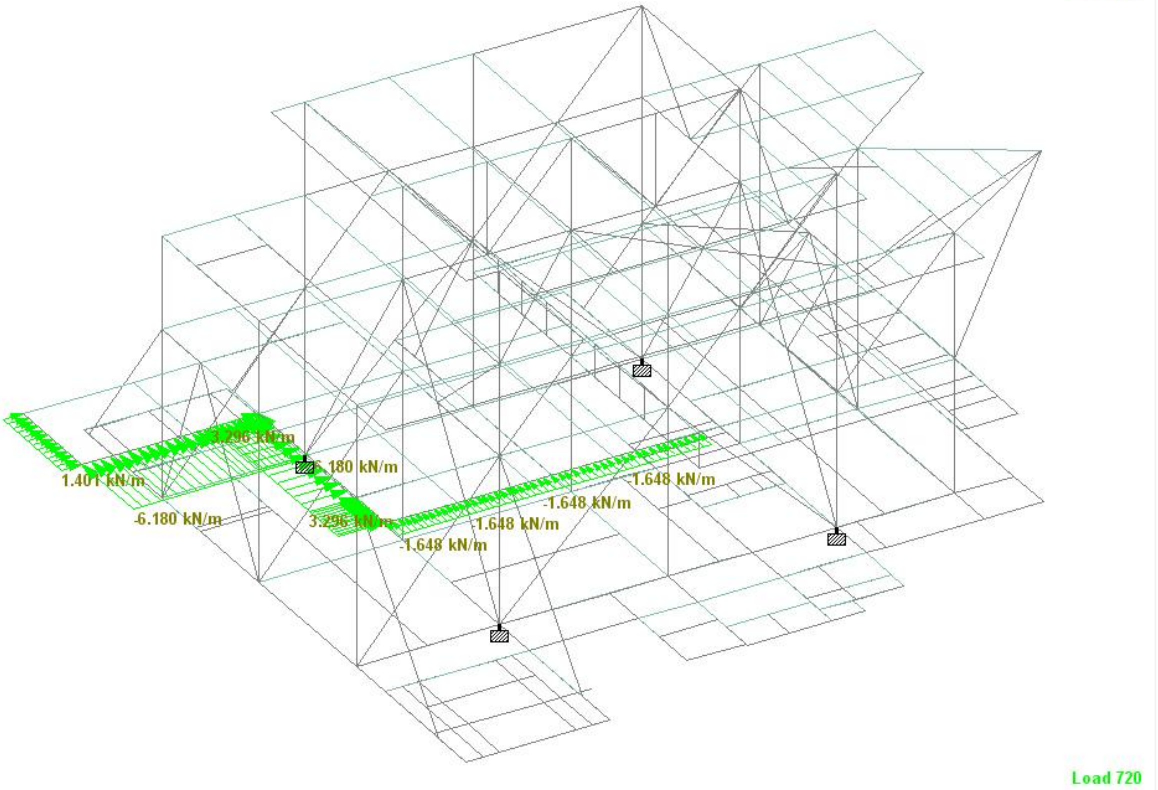
3.961 kN/m
1.981 kN/m
1.981 kN/m
1.981 kN/m
3.961 kN/m
2.773 kN/m
2.773 kN/m
5.942 kN/m
5.942 kN/m
5.942 kN/m
5.942 kN/m
5.942 kN/m
5.942 kN/m
5.942 kN/m
7.130 kN/m
Load 640


3.404 kN/m
3.404 kN/m
3.404 kN/m
3.404 kN/m
2.553 kN/m
2.553 kN/m
2.553 kN/m
Load 700


4.192 kN/m
4.192 kN/m
4.192 kN/m
-2.515 kN/m
-2.515 kN/m
-1.677 kN/m
1.677 kN/m
-1.677 kN/m
-1.886 kN/m
1.886 kN/m
Load 710


3.296 kN/m
6.180 kN/m
1.401 kN/m
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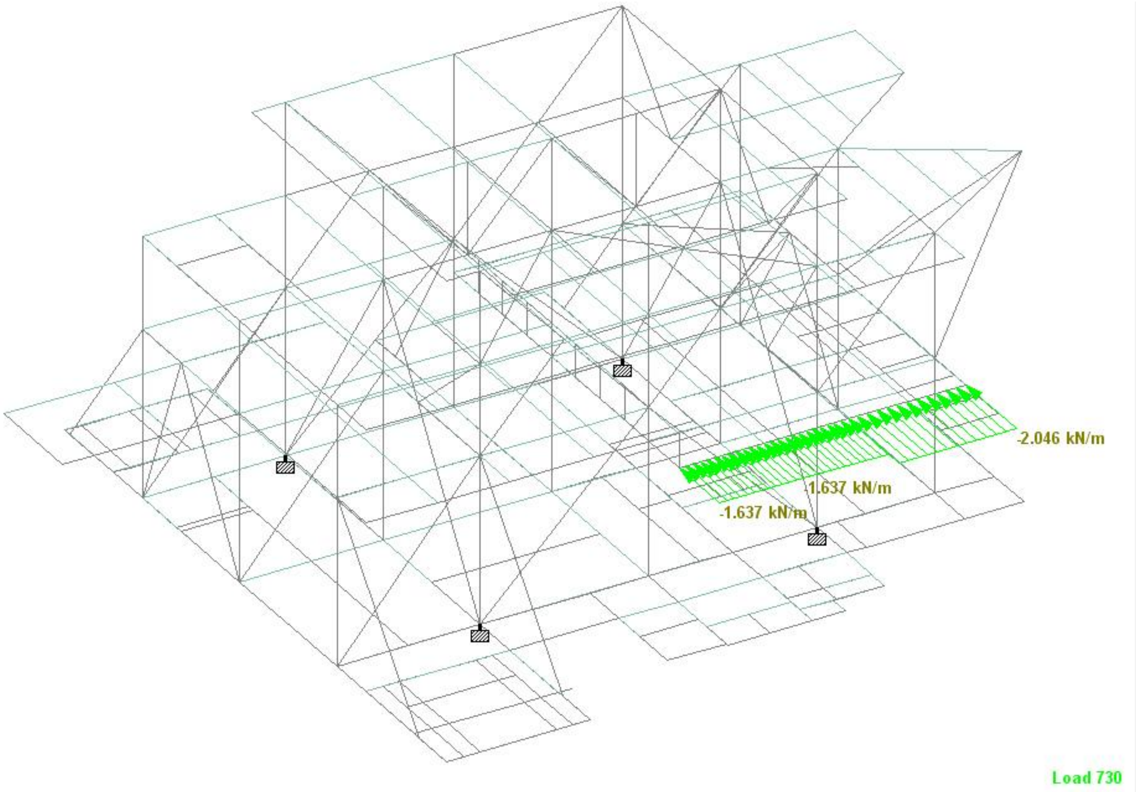
-1.648 kN/m
-1.648 kN/m
-1.648 kN/m
-1.648 kN/m
Load 720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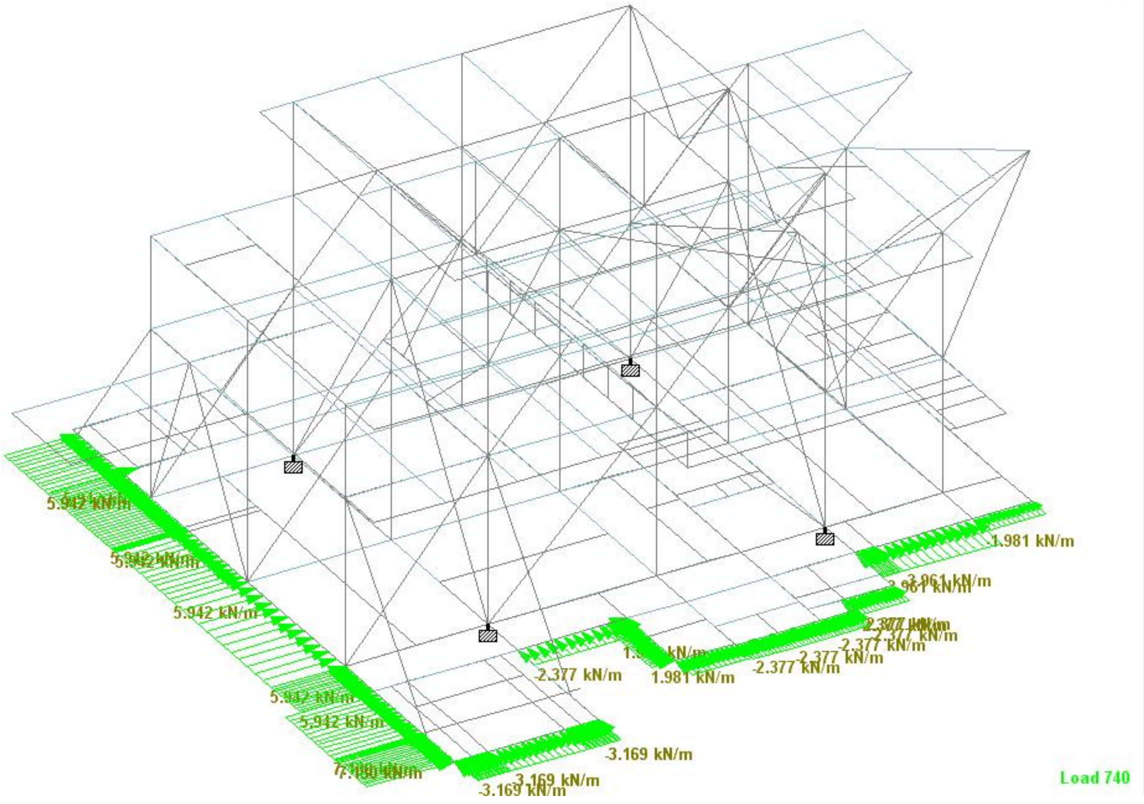
Load 730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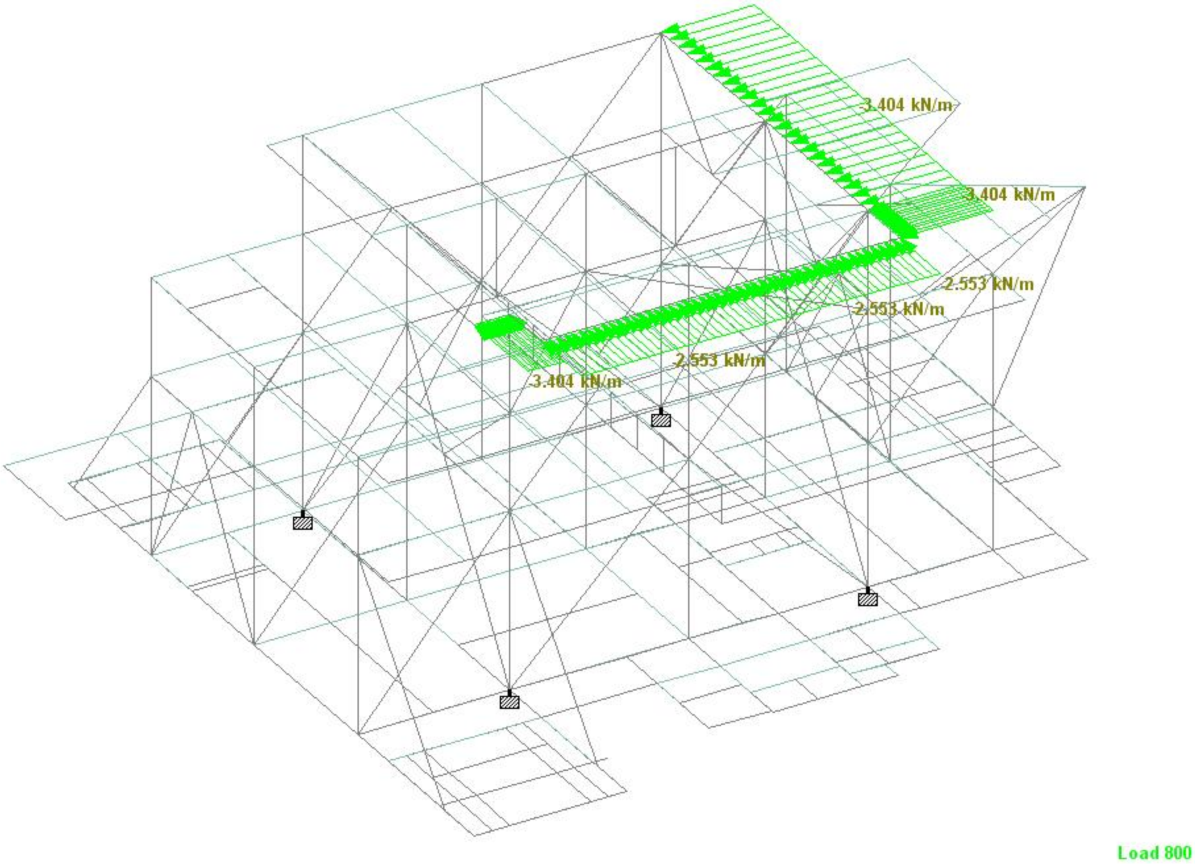
5.942 kN/m
5.942 kN/m
1.981 kN/m
3.961 kN/m
-2.377 kN/m
-2.377 kN/m
-2.377 kN/m
-2.377 kN/m
-2.377 kN/m
1.981 kN/m
-2.377 kN/m
-3.169 kN/m
-3.169 kN/m
-3.169 kN/m
Load 740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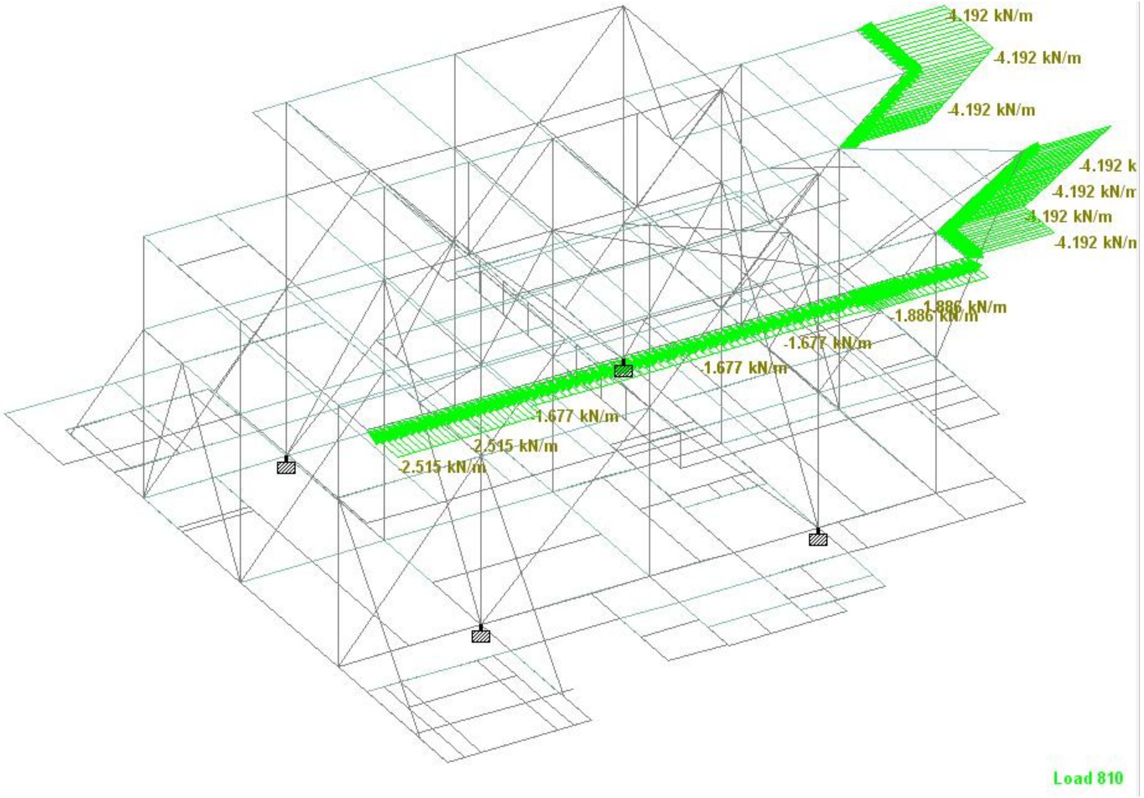
Load 800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-4.192 kN/m
-4.192 kN/m
-4.192 k
-4.192 kN/r
-4.192 kN/m
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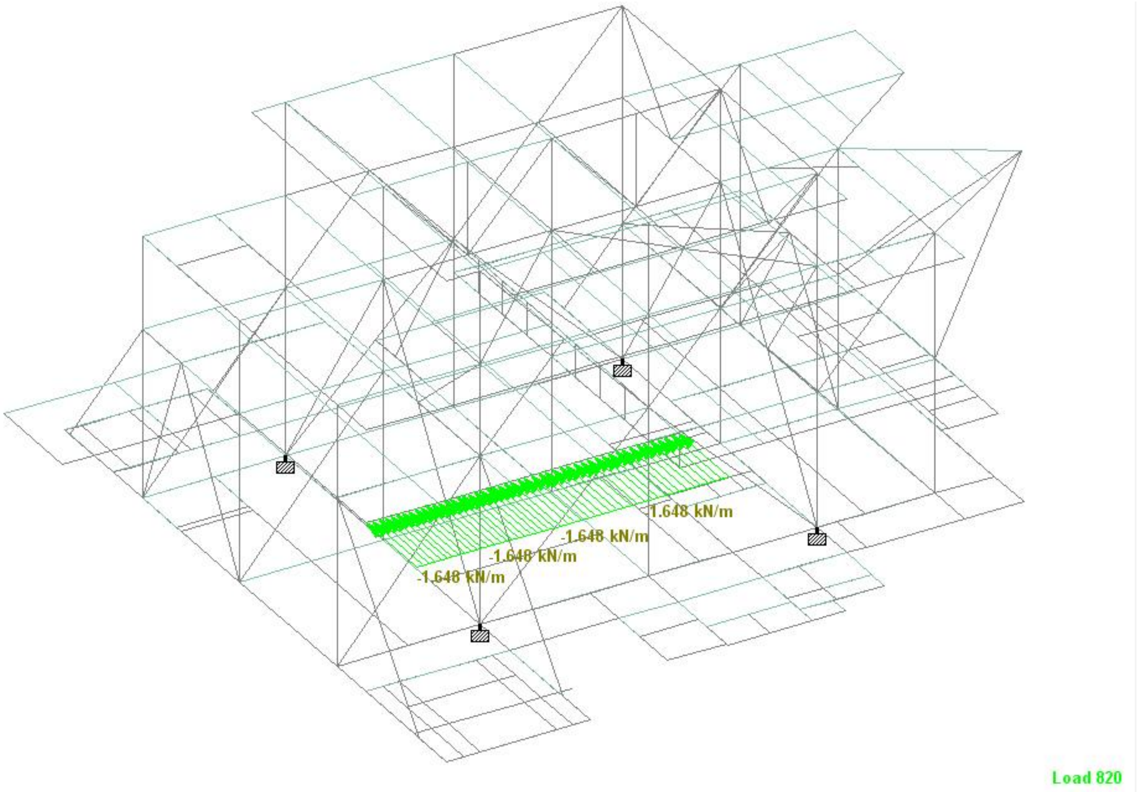
-1.886 kN/m
-1.886 kN/m
-1.677 kN/m
-1.677 kN/m
-1.677 kN/m
-2.515 kN/m
-2.515 kN/m
Load 810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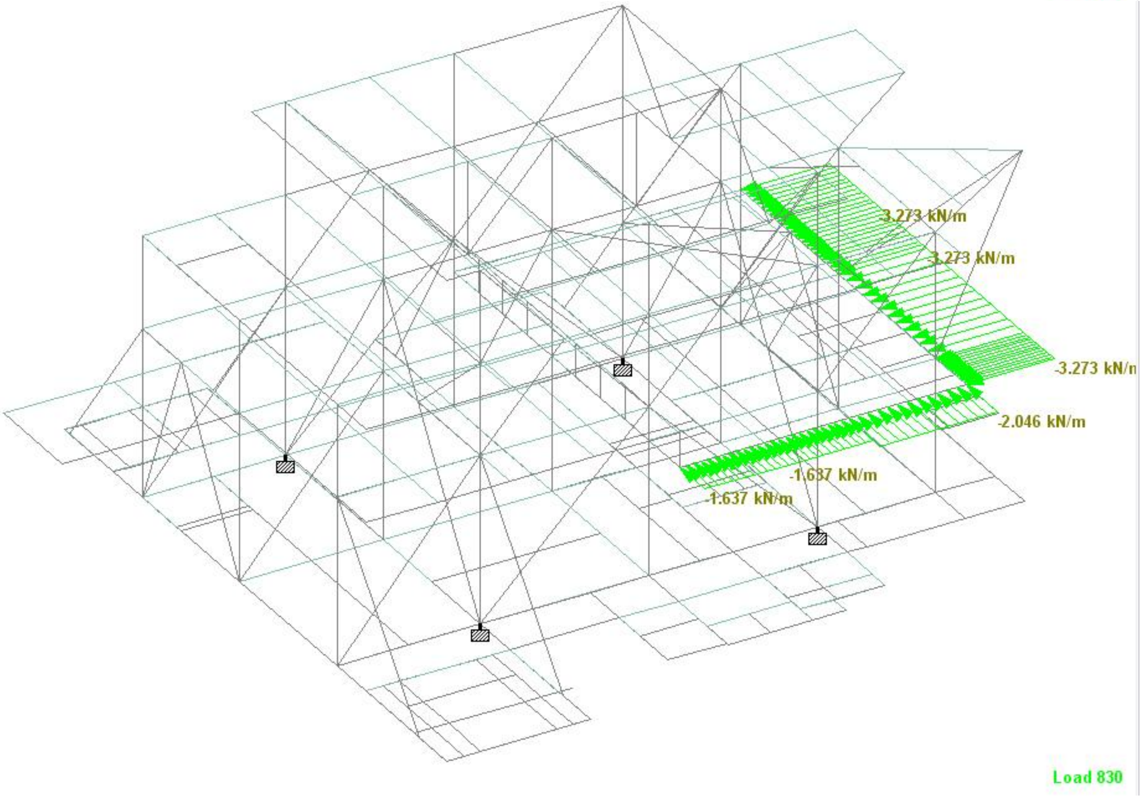
Load 820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-3.273 kN/m
-3.273 kN/m
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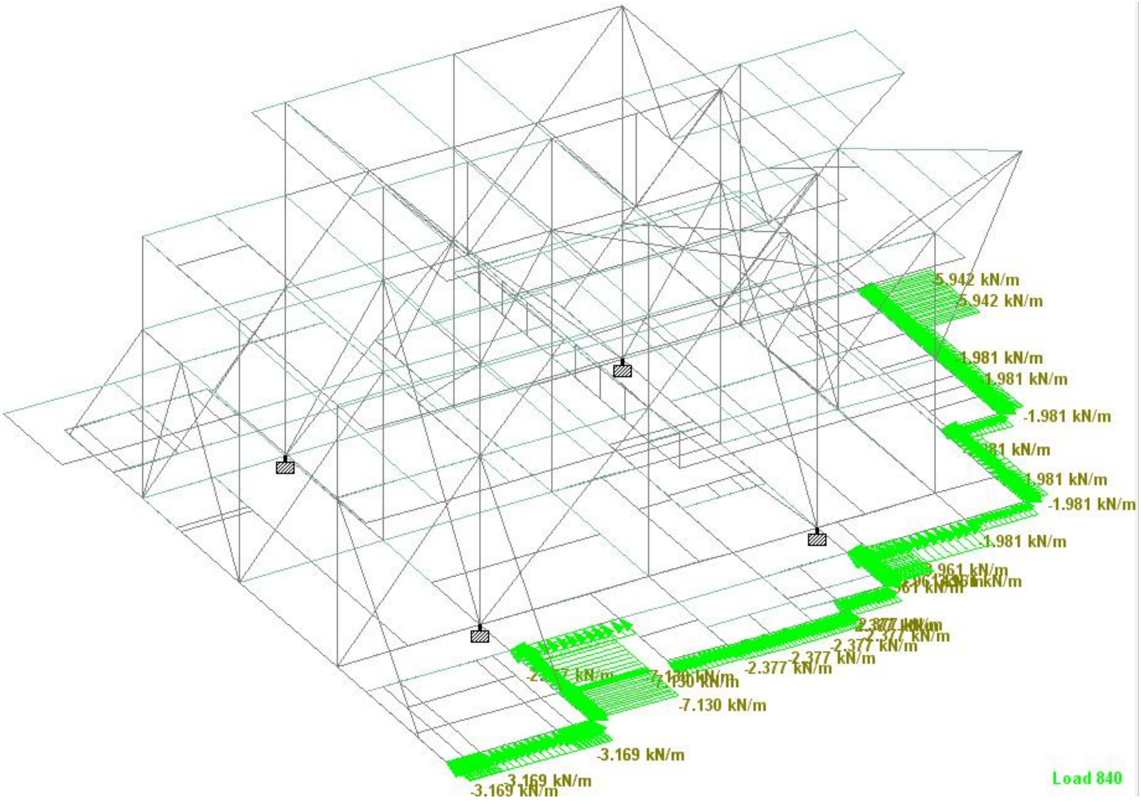
-1.637 kN/m
Load 830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5.942 kN/m
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-7.130 kN/m
-7.130 kN/m
-3.169 kN/m
-3.169 kN/m
-3.169 kN/m
Load 840

D. DRAWINGS OF THE PLATFORM