Appendix to report:

SBJ-33-C5-OON-22-RE-012
STRUCTURAL RESPONSE ANALYSES

Appendix title:

APPENDIX A – GEOMETRY INPUT

Contract no:	18/91094
Project number:	5187772/12777
Document number:	SBJ-33-C5-OON-22-RE-012 App. A
Date:	15.08.2019
Revision:	0
Number of pages:	24
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CONCEPT DEVELOPMENT FLOATING BRIDGE E39 BJØRNAFJORDEN

Table of Content

1 INTRODUCTION

The model input can currently be found on the webpage Olav Olsen Interactive [1] for K12 – Model 20. Most relevant input will also be presented here in the final version of this document.

2 GLOBAL GEOMETRY

2.1 Global input

Most relevant global input parameters of the bridge is presented in Table 2-1.

> *Table 2-1 Global parameters*

Parameter	Value	Unit
Flight distance	5176	m
Radius of bridge	5000	m
Arc length of bridge	5440	m
Length of cable stayed bridge	710	m
Height of cable stayed tower	216	m
Length of high floating bridge	Ca. 1190	m
Length of low floating bridge	Ca. 3540	m
Pontoon distance	120	m
Number of pontoons	39	-
Number of anchor groups	2	-
Number of pontoons per anchor group	4	-
Number of anchor lines per pontoon	2	-

2.2 Boundary conditions

The following boundary conditions have been applied in the structural analysis model.

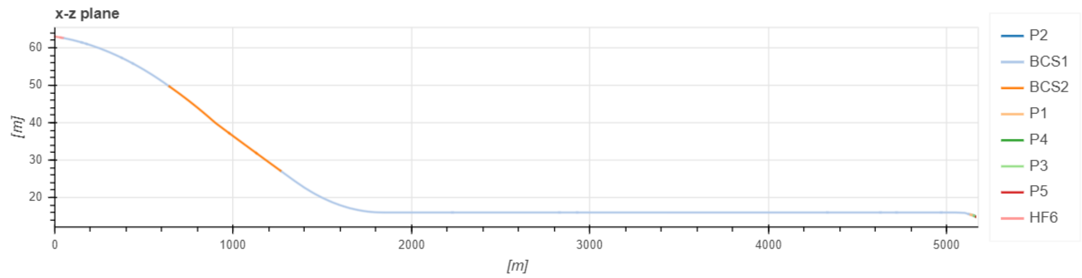
1) The bridge is fixed for all translations and rotations at both landsides
2) The cable stayed tower is fixed for all translations at both cable stayed tower legs.
3) The five first cable stays towards the landside in south are fixed for all translations.

3 BRIDGE GIRDER CROSS SECTION

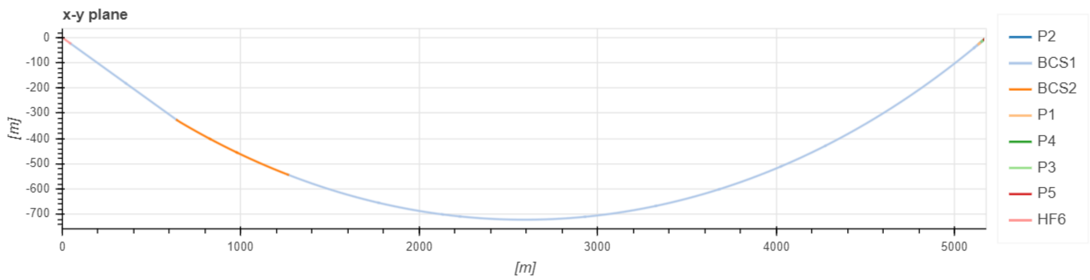
In this chapter the different bridge girders cross section that have been applied in the structural analysis model is presented. The cross sections BCS1, BCS2 and HF6 are presented. The remaining sections P1 to P5 have very small distributions towards the ends and are basically interpolations of BCS1 and HF6. More information about these cross sections are found on olavolsen.interactive.no [1].

3.1 Outline of the bridge sections

An outline of where the different cross sections are applied in the structural is illustrated in Figure 3-1 and Figure 3-2 below.



> *Figure 3-1 Outline of bridge girder section seen from the side (orange=BCS2, blue=BCS1)*

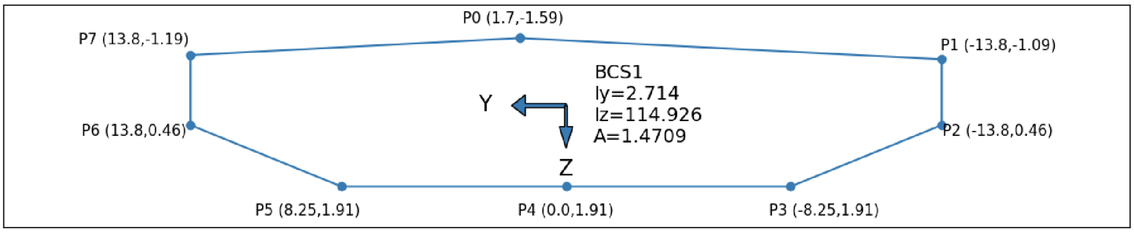


> *Figure 3-2 Outline of bridge girder section seen from the side (orange=BCS2, blue=BCS1)*

3.2 Cross sections

An illustration of the cross section along with cross sectional parameters are presented in Figure 3-3 and Table 3-1 respectively.

3.2.1 BCS1 – The main span bridge girder cross section



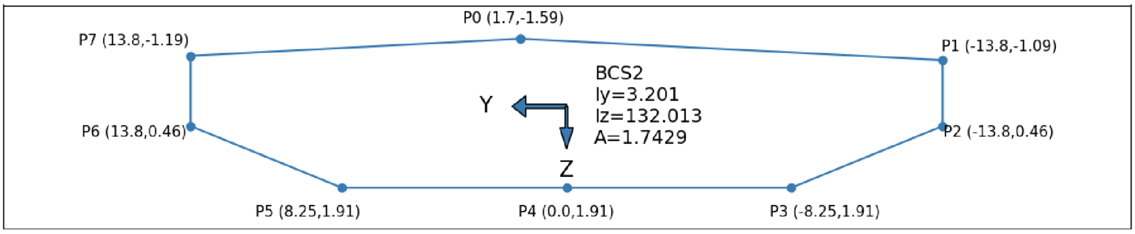
> *Figure 3-3 BCS1 Cross section*

> *Table 3-1 BCS1 Cross sectional parameters*

Parameter	Value	Unit
A – Structural steel area	1.4709	m^2
Ix - Torsional second area moment	6.55	m^2
Iy - Weak axis second area moment	2.714	m^4
Iz – Strong axis second area moment	114.926	m^4
Width of structural cross section	27.6	m
Height of structural cross section	3.5	m
Axial steel weight	11547	kg/m
Transverse steel weight	1206	kg/m
Weight of asphalt	4600	kg/m
Weight of other equipment	500	kg/m
Total weight of cross section	17853	kg/m

3.2.2 BCS2 – The main span reinforced bridge girder cross section

An illustration of the cross section along with cross sectional parameters are presented in Figure 3-4 and Table 3-2 respectively.



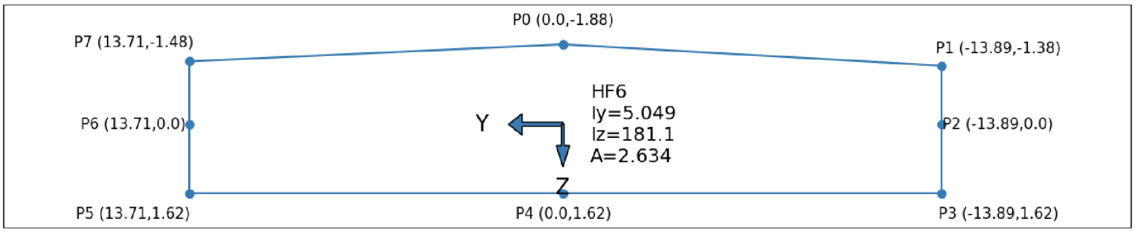
> *Figure 3-4 BCS2 Cross section*

> *Table 3-2 BCS2 Cross sectional parameters*

Parameter	Value	Unit
A – Structural steel area	1.7429	m^2
Ix - Torsional second area moment	6.74	m^2
Iy - Weak axis second area moment	3.201	m^4
Iz – Strong axis second area moment	132.01	m^4
Width of structural cross section	27.6	m
Height of structural cross section	3.5	m
Axial steel weight	13682	kg/m
Transverse steel weight	1206	kg/m
Weight of asphalt	4600	kg/m
Weight of other equipment	500	kg/m
Total weight of cross section	19988	kg/m

3.2.3 HF6 – The end reinforcement bridge girder cross section

An illustration of the cross section along with cross sectional parameters are presented in Figure 3-5 and Table 3-3 respectively.



> *Figure 3-5 HF6 Cross section*

> *Table 3-3 HF6 Cross sectional parameters*

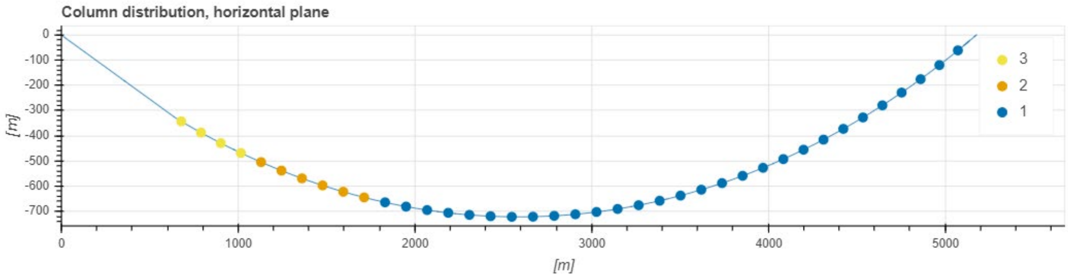
Parameter	Value	Unit
A – Structural steel area	2.634	m^2
Ix - Torsional second area moment	10.9	m^2
Iy - Weak axis second area moment	5.049	m^4
Iz – Strong axis second area moment	181.1	m^4
Width of structural cross section	27.6	m
Height of structural cross section	3.5	m
Axial steel weight	20679.9	kg/m
Transverse steel weight	1137	kg/m
Weight of asphalt	4600	kg/m
Weight of other equipment	500	kg/m
Total weight of cross section	26260	kg/m

4 PONTOON COLUMNS

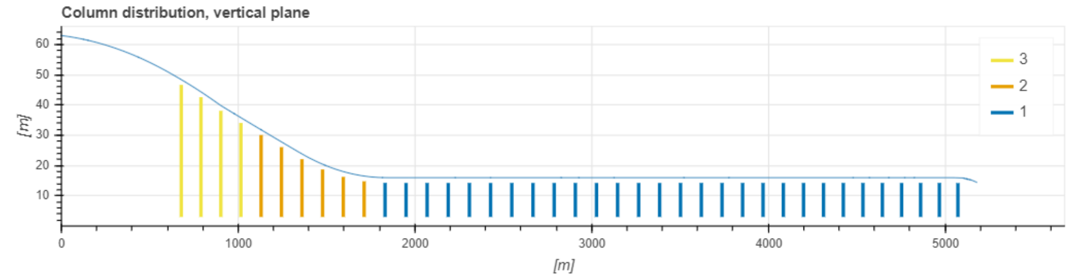
Three different pontoon column cross sections have been applied in the global analyses.

4.1 Outline of pontoon columns

An outline of where the different pontoon column cross sections have been applied is seen in Figure 4-1 and Figure 4-2.

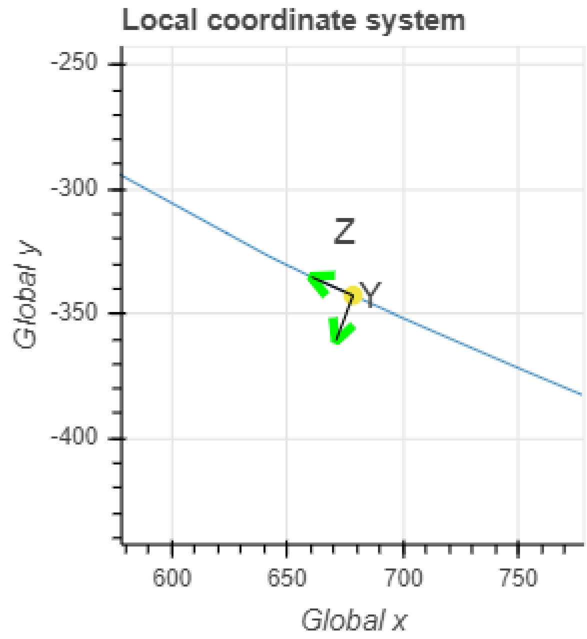


> *Figure 4-1 Outline of pontoon columns seen from above*

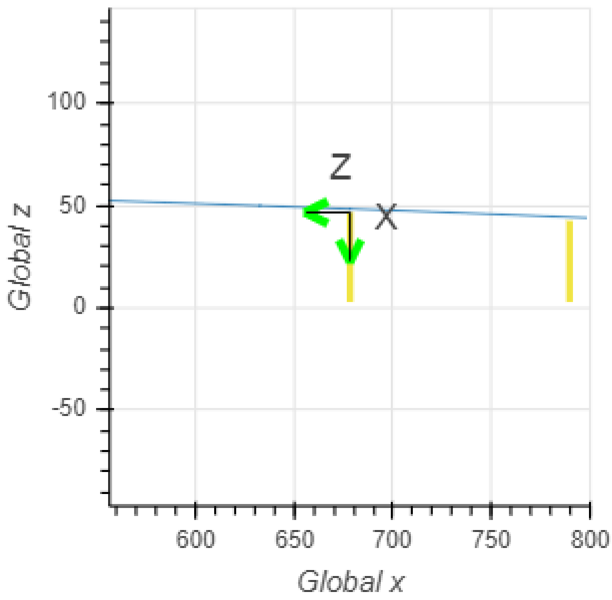


> *Figure 4-2 Outline of pontoon columns seen from the side*

The direction of each pontoon tower is aligned with the normal vector of the bridge girder. See the local directions in Figure 4-3 and Figure 4-4.



> *Figure 4-3 Local direection seen from above*



> *Figure 4-4 Local directions seen from the side*

4.2 Cross sectional properties

Most relevant cross sectional properties for the three different kinds of pontoon column cross sections applied in the global analyses are presented in Table 4-1.

> *Table 4-1 Pontoon columns cross sectional propperties*

Geometric properties	CS1	CS2	CS3
Cdy [-]	0.4	0.4	0.4
Cdz [-]	1.6	1.6	1.6
Solid area [m^2]	1.47	1.47	1.47
Iy [m4]	3.57	3.57	3.57
Iz [m^4]	20.89	20.89	20.89
J [m^4]	24.46	24.46	24.46
Ly [m]	12	12	12
Lz [m]	4	4	4
Mass/m [kg/m]	15500	13204	13204

4.3 Pontoon tower quantities

Relevant pontoon tower quantities are displayed in Table 4-2.

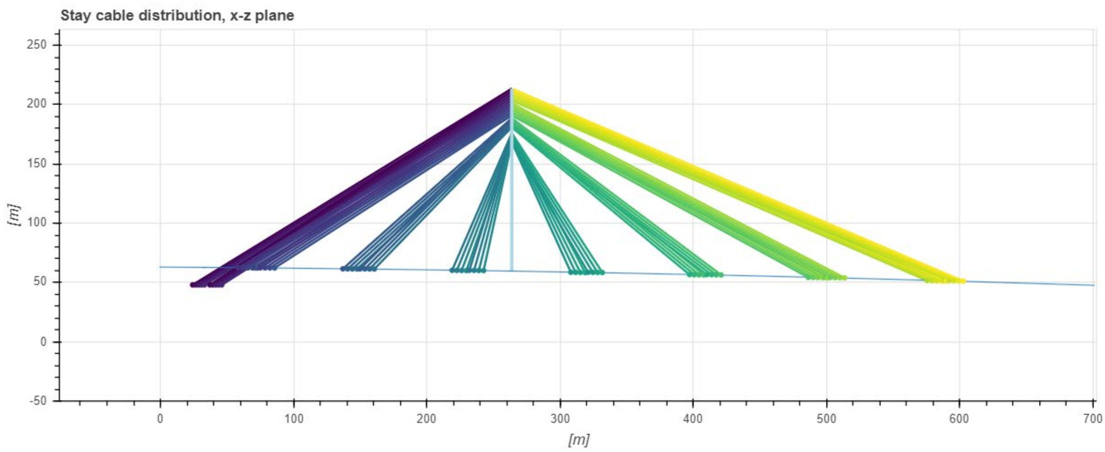
> *Table 4-2 Pontoon column quantities*

Total amounts	Number of #	Total Length [m]	Total mass [kg]
CS1	29	326	5,055,148
CS2	6	110	1,452,727
CS3	4	149	1,973,551

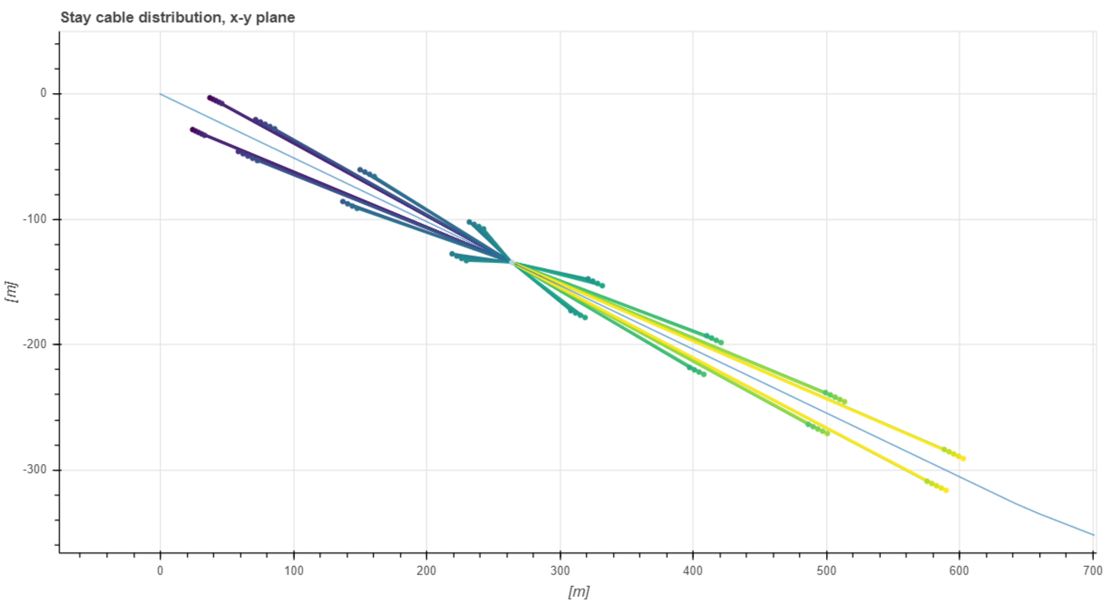
5 STAY CABLES

5.1 Outline of stay cables

An outline of the cable stays applied in the global model is seen in Figure 5-1 and Figure 5-2. Each stay cable has a somewhat different input properties (area, length, mass, pre-strain and Youngs-modulus (corrected with regards to length)..etc). For full information with regards to these properties, go to olavolsen.interactive.no and see K12-model 27 [1].



> *Figure 5-1 Stay cable seen from the side*



> *Figure 5-2 Stay cable seen from above*

5.2 General cross sectional properties

The general cross sectional properties applied for all cable stays are seen in Table 5-1.

> *Table 5-1 General cross sectional propperites*

Amount	Values
Cdy	0.8
Cdn	0.8
E-modulus (Not corrected for cable length) [GPa]	160

5.3 Quantities of cable stays

The main quantities of the cable stays are summarized in Table 5-2.

> *Table 5-2 Main quantities of the cable stays*

Amount	Values
Total Volume [m3]	160
Total Strand length [km] (each has an area of 150E-6 m^2)	1067
Total cable length [m]	17644
Number of cables [-]	72
Total steel mass [ton]	1252

6 STAY CABLE TOWER

The cable stayed tower consists of two main parts. The top, which have a consistent cross section through the entire part, and the two legs, which have expanding cross sections towards the bottom.

6.1 Cable stayed top

The applied structural properties for the stay cable tower top is seen in Table 6-1.

> *Table 6-1 Structural properties for stay cable tower top.*

Geometric properties	CS1
Height [m]	6
Width [m]	6
Cdy [-]	2
Cdz [-]	2
Solid area [m^2]	21.6
Iy [m4]	92.48
Iz [m^4]	88.8
J [m^4]	181.2
Top elevation [m]	216
Bottom elevation [m]	166.7

6.2 Cable stayed legs

The applied structural properties for the stay cable tower legs is seen in Table 6-1.

> *Table 6-2 Structural properties for stay cable tower legs (two of them).*

Geometric properties	Cross section top	Cross section bottom
Height [m]	4	6
Width [m]	6	15
Cdy [-]	2	2
Cdz [-]	2	2
Solid area [m^2]	16.8	39.6
Iy [m4]	64.2	202.8
Iz [m^4]	29.6	1020.7
J [m^4]	93.8	1223.5
Top elevation [m]	166.7	-
Bottom elevation [m]	-	0

The top elevation of the legs is 166.7m while the bottom elevation is 0m. The tower cross sectional properties are interpolated in between these two elevations.

6.3 Orientation of the tower

The tower is oriented so that the local y-direction of the legs and tower top are parallel with the bridge girder. The local z-direction of the tower top and tower legs are normal on the bridge girder.

The bottom of the legs are placed 58m apart in a direction normal on the bridge girder.

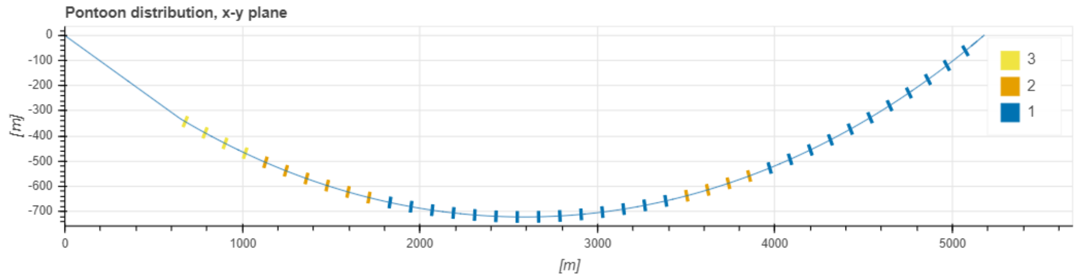
The tower legs are leaning towards the landfall in the south. The bottom and top of the legs have an offset of about 14m in a direction parallel to the bridge girder.

7 PONTOON

In all three different pontoon types have been applied in the final global model.

7.1 Outline of pontoons

The outline of the three different pontoon types are seen in Figure 7-1.



> *Figure 7-1 Pontoon outlines*

All pontoons are aligned in a direction normal to the bridge girder.

7.2 General information

General information about the different pontoon types are seen in Table 7-1.

> *Table 7-1 General information*

Pontoon input	1	2	3	
Length of pontoon	58	58	58	[m]
Width of pontoon	12	14.5	17	[m]
Height of pontoon	9	9	9	[m]
Draft of pontoon	5	5	5	[m]
Center of gravity pontoon	-0.5	-0.5	-0.5	[m]
Center of bouyancy	-2.5	-2.5	-2.5	[m]
Height of pontoon above surface	4	4	4	[m]
Area of pontoon at WL	665.0973	795.8799639	923.9800692	[m^2]
Circumferce of pontoon at WL	129.6991	132.5530935	135.4070751	[m]
Volume of pontoon	5985.876	7162.919675	8315.820623	[m^3]
Displacement of pontoon	3325.487	3979.399819	4619.900346	[m^3]
Total surface area of pontoon	2497.487	2784.737769	3066.623814	[m^2]
Mass of ballast	85323	472682	540357	[kg]
Weight of pontoon	897881	1074438	1247373	[kg]
Weight of pontoon including ballast	983204	1547120	1787730	[kg]
Water plane heave stiffness	6687720	8002772.007	9290850.591	[N/m]
Water plane roll 2. moment	7641.876	13221.17656	20885.91083	[m^4]
Water plane pitch 2. moment	172163.8	203414.0606	233652.4027	[m^4]
Water plane roll stiffness	76840974	132942235.6	210013054.9	[Nm/rad]
Water plane pitch stiffness	1.73E+09	2045379233	2349433322	[Nm/rad]

7.3 Quantities of pontoons

A summary of the pontoon quantities are found in Table 7-2.

> *Table 7-2 Pontoon quantites*

Pontoon ID	Number of #	Total displacement [m3]	Total mass [kg]	Total steel mass [kg]
1	25	83,120	24,572,250	22,442,670
2	10	39,787	15,471,169	10,742,651
3	4	18,477	7,150,596	4,988,800
total	39	141,385	47,194,016	38,174,122

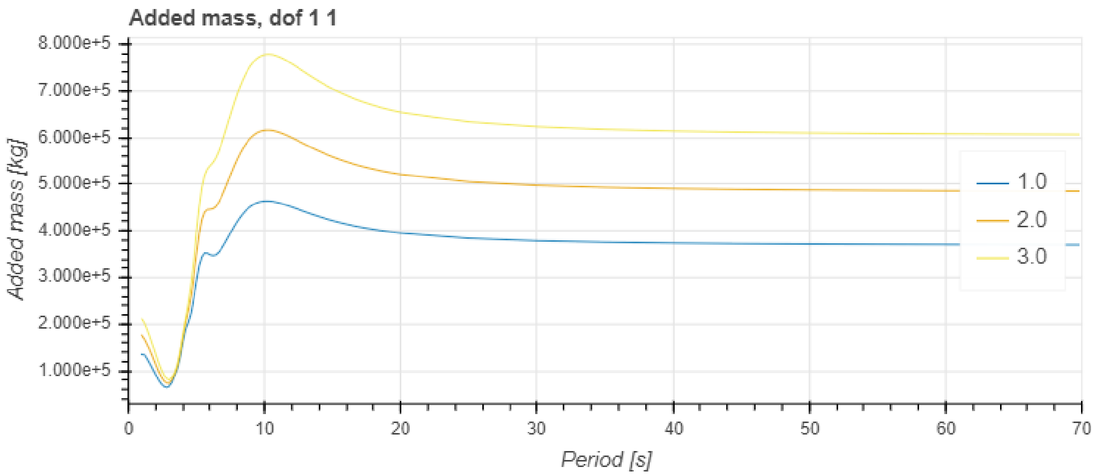
7.4 Linear potential elements

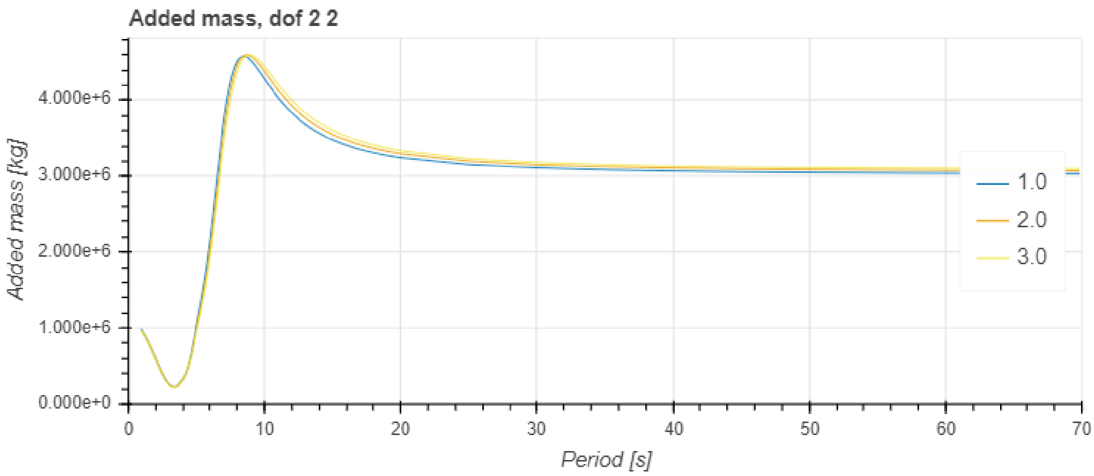
The frequency dependent damping, added mass and exiting forces of the pontoons are represented by a potential elements calculated by use of WADAM [2]. The method applied to transfer the potential theory to the global dynamic model is further explained in SBJ-33-C5-OON-22-RE-003 App A Hydrostatic and hydrodynamic coefficients [3].

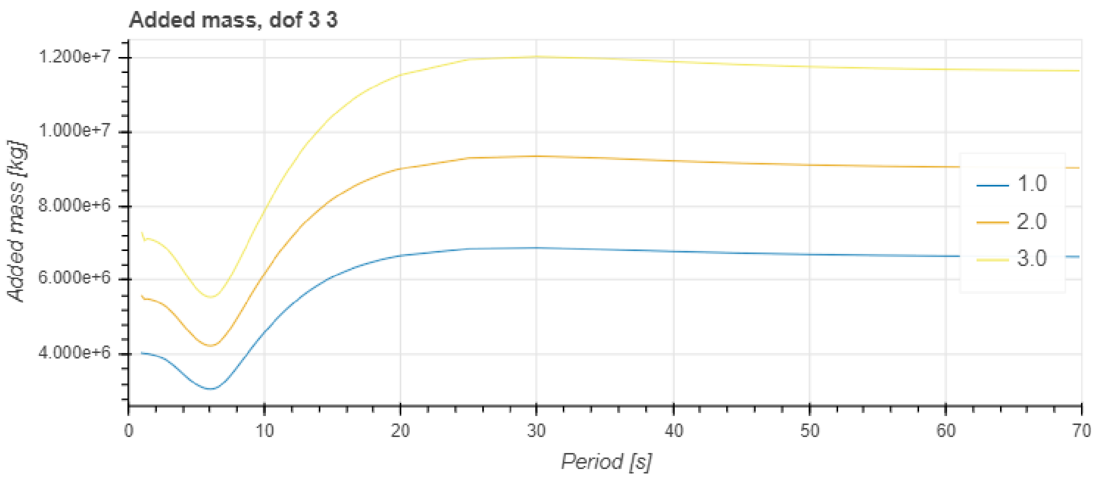
Only a limited presentation of the potential theory elements will be presented here. For further details see www.interactive.olavolsen.no K12 – model 27 [1].

7.4.1 Added mass input

The frequency dependent added mass applied for each pontoon type is seen below for surge, sway, and heave respectively.

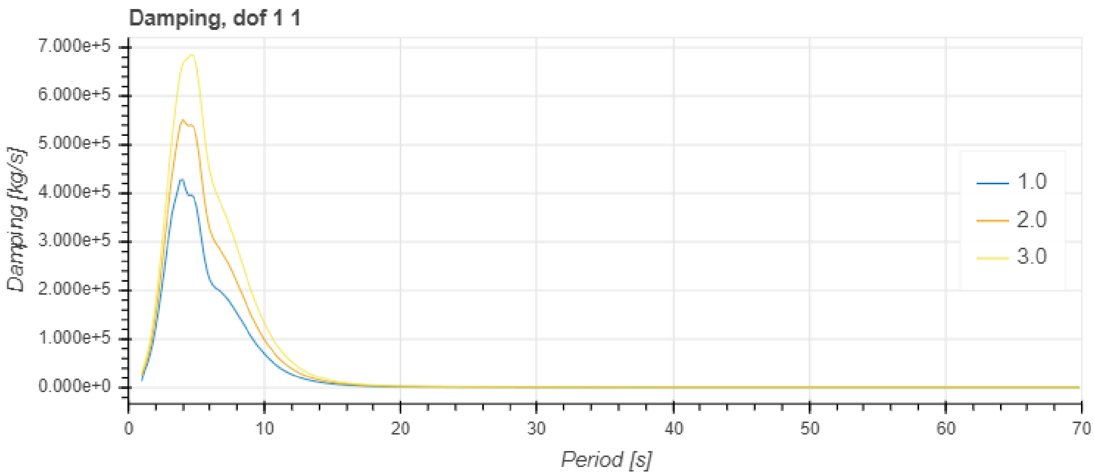


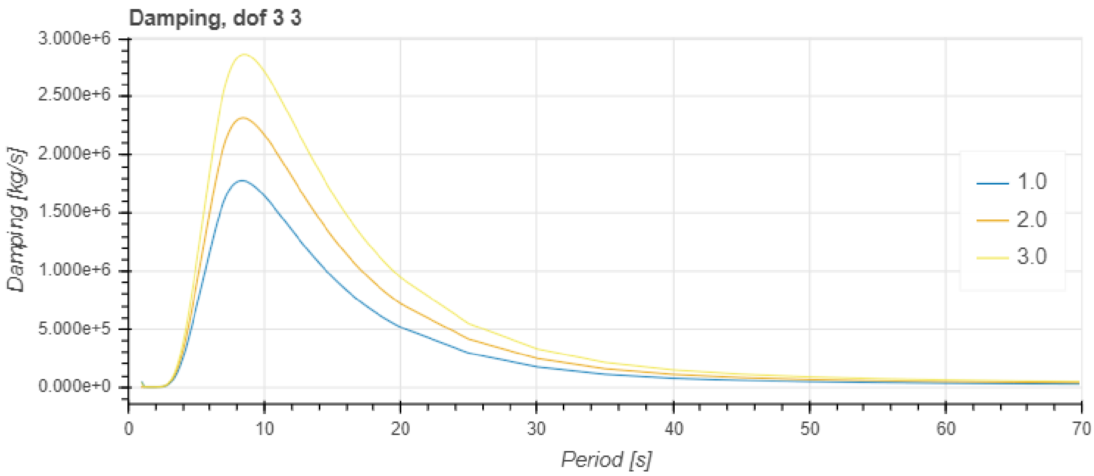


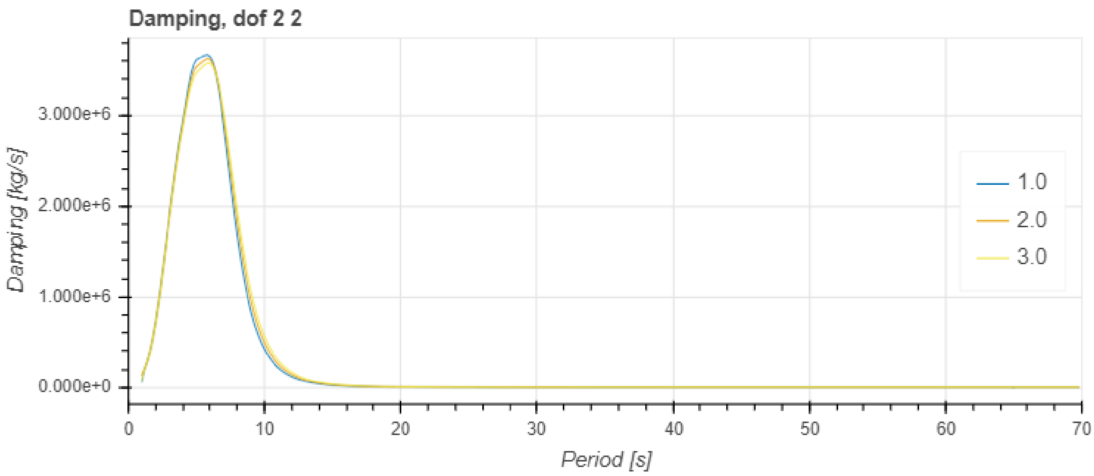


7.4.2 Damping input

The frequency dependent damping applied for each pontoon type is seen below for surge, sway, and heave respectively.

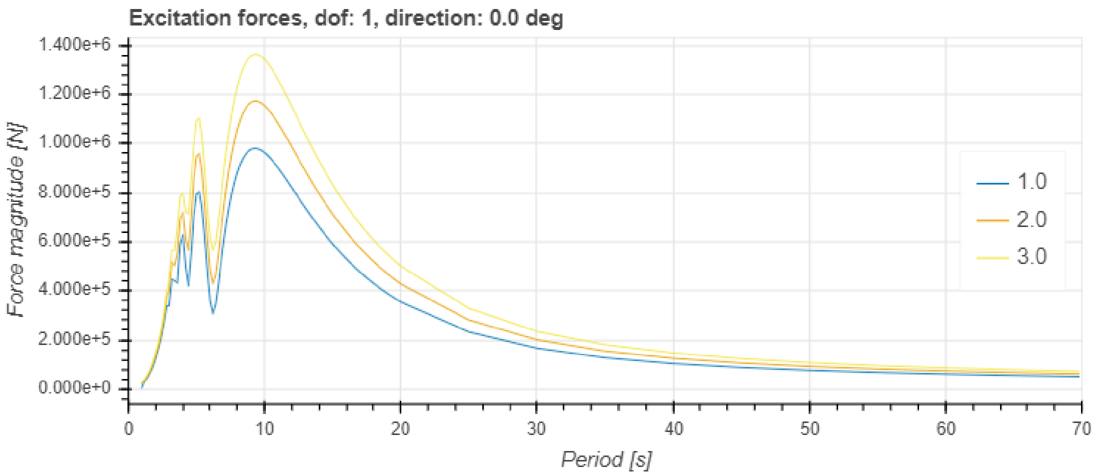


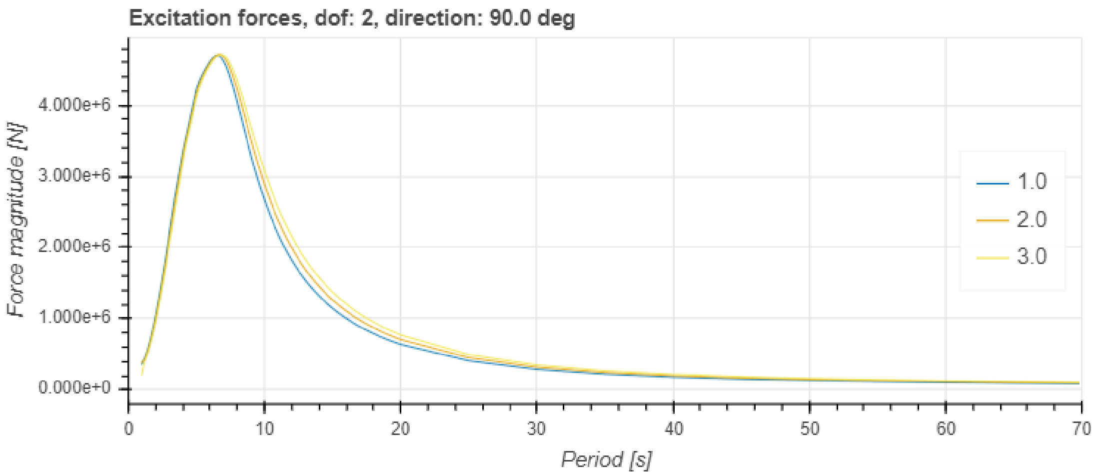


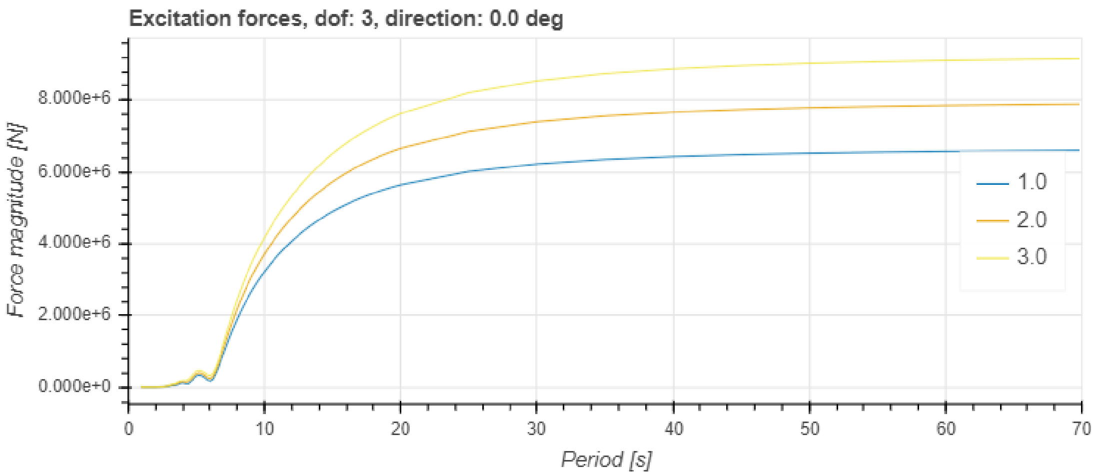


7.4.3 Excitation forces

The frequency dependent excitation forces applied for each pontoon type is seen below for surge for waves in surge direction , sway for waves in sway direction, and heave for waves in surge direction, respectively.

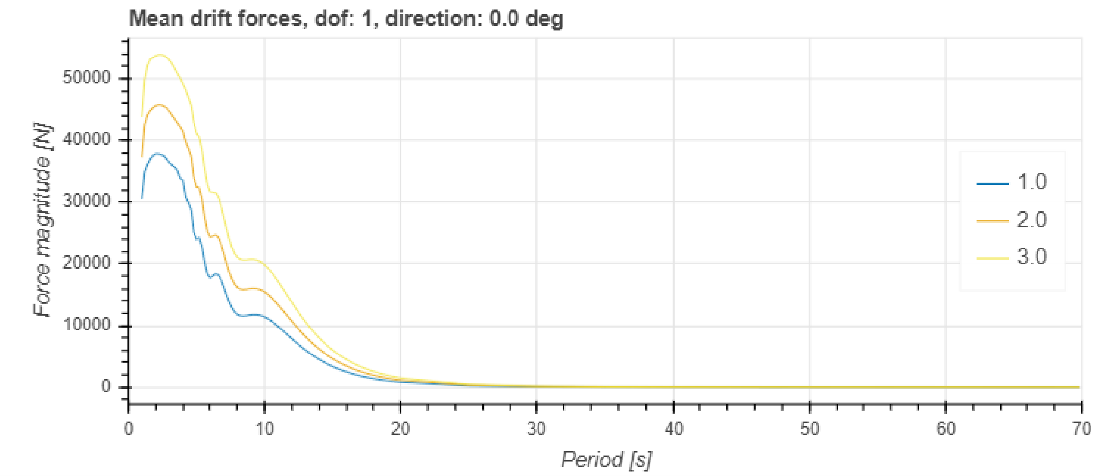


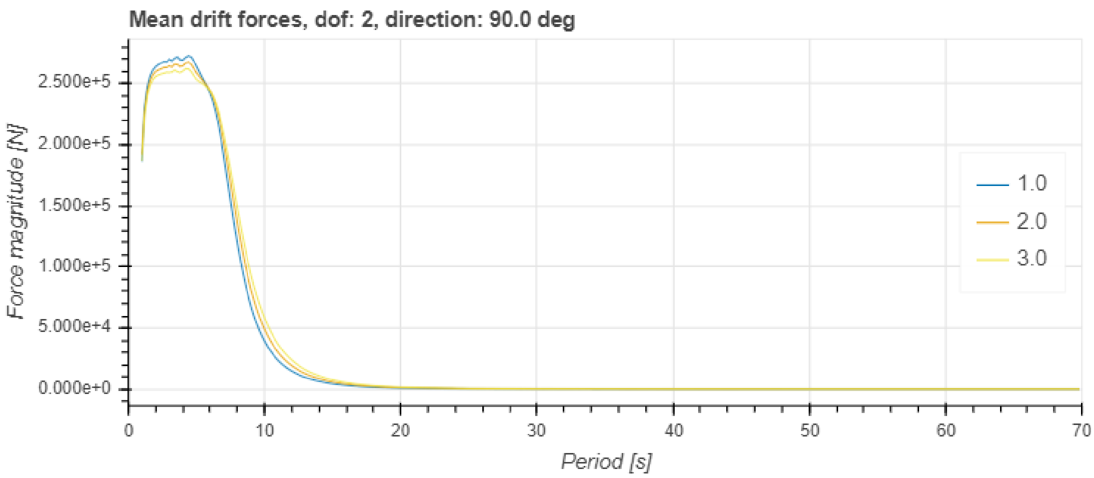


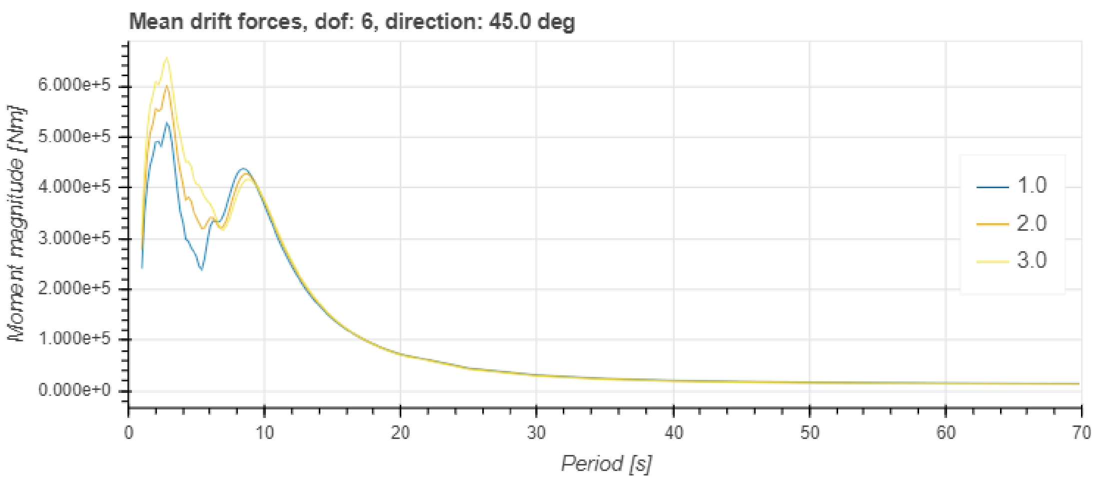


7.4.4 Mean drift forces

The frequency dependent mean drift forces applied for each pontoon type is seen below for surge for waves in surge direction , sway for waves in sway direction, and gear for waves coming in from a 45 degree direction, respectively.







8 REFERENCES

[1] Olav Olsen, Olav Olsen interactive; Project Bjørnafjorden phase 5, Oslo.

[2] DNV, WADAM User Manual, 2010.

[3] Olav Olsen, Norconsult, SBJ-33-C5-OON-22-RE-003 App A Hydrostatic and hydrodynamic coefficients, Oslo, 2019.

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