Appendix to report:

SBJ-33-C5-OON-22-RE-012

STRUCTURAL RESPONSE ANALYSES

Appendix title:

APPENDIX D – GLOBAL STABILITY EVALUATIONS

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CONCEPT DEVELOPMENT FLOATING BRIDGE E39 BJØRNAFJORDEN

Table of Content

1 INTRODUCTION

In this report the stability of the floating bridge is evaluated for five different stages/situations;

- Operational phase with traffic
- Operational phase without traffic
- Floating phase (clean girder)
- Loss of pontoon and tower (adjacent pontoons must maintain stability)

The last scenario is a somewhat unrealistic situation. Basically, we extract one of the pontoons from the bridge. This is a very conservative approach and goes far beyond any scenarios in the design basis. The load span related to a pontoon increases from 120m to 180m which of course decreases the stability. But if we still can maintain a decent global stability at this situation, this shows us that global stability most likely never will be an issue with regards to the presented concept.

2 STRUCTURAL INPUT

Input values applied in the global stability evaluation is presented in sections below.

2.1 General input

The general input to this global stability evaluation is presented in Table 2-1.

> *Table 2-1 General input*

General input		
Water density	1025	[kg/m^3]
Gravity constant	9.81	[m/s^2]
Specific density steel	7850	[kg/m^3]
Span length	120	[m]
Span length – loss of pontoon	180	[m]

2.2 Pontoons

Relevant pontoon information is presented in Table 2-2.

> *Table 2-2 Pontoon 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]
Steel thickness	0.02	0.02	0.02	[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	665.0973355	795.8799639	923.9800692	[m^2]
Circumferce of pontoon at WL	129.6991118	132.5530935	135.4070751	[m]
Volume of pontoon	5985.87602	7162.919675	8315.820623	[m^3]
Displacement of pontoon	3325.486678	3979.399819	4619.900346	[m^3]
Total surface area of pontoon	2497.486678	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	6687719.983	8002772.007	9290850.591	[N/m]
Water plane roll 2. moment	7641.87602	13221.17656	20885.91083	[m^4]
Water plane pitch 2. moment	172163.7525	203414.0606	233652.4027	[m^4]
Water plane roll stiffness	76840973.85	132942235.6	210013054.9	[Nm/rad]
Water plane pitch stiffness	1731149572	2045379233	2349433322	[Nm/rad]

2.3 Columns

Column information is presented in Table 2-3.

> *Table 2-3 Column information*

Column input	1	2	3	
Cross section width of tower	12	12	12	[m]
Cross section height of tower	4	4	4	[m]
Total weight/m	15500	13200	13200	[kg/m]
Total weight (Force)/m	152013	129493	129493	[N/m]
Height of column	9.25	24.25	39.25	[m]
Center of gravity	8.625	16.125	23.625	[m]
Weight of column	143375	320100	518100	[kg]
Weight of column top/girder reinforcement	120000	120000	120000	[kg]
Center of gravity reinforcement	13.25	28.25	43.25	[m]

2.4 Bridge girder

The bridge girder information is presented in Table 2-4.

> *Table 2-4 Bridge girder information*

Bridge grider input	1	2	3	
Area	1.4709	1.7429	1.7429	[m^2]
Steel weight twin box	11546.565	13681.765	13681.765	[kg/m]
Second order steel	1206	1206	1206	[kg/m]
Asphalt	4600	4600	4600	[kg/m]
Other	500	500	500	[kg/m]
Traffic weight	3010	3010	3010	[kg/m]
Bridge girder elevation (cog)	15	30	45	[m]
Mass per meter with traffic	20862.565	22997.765	22997.765	[kg/m]
Mass per meter without traffic	17852.565	19987.765	19987.765	[kg/m]
Mass per meter floating	12752.565	14887.765	14887.765	[kg/m]
Average mass projected to pontoon with traffic	2503507.8	2759731.8	2759731.8	[kg]
Average mass projected to pontoon without traffic	2142307.8	2398531.8	2398531.8	[kg]
Average mass projected to pontoon installation phase	1530307.8	1786531.8	1786531.8	[kg]
Average mass projected to pontoon without traffic but with loss of pontoon	3213461.7	3597797.7	3597797.7	[kg]
Average load projected to pontoon with traffic	24559411.52	27072968.96	27072968.96	[N/m]
Average load projected to pontoon without traffic	21016039.52	23529596.96	23529596.96	[N/m]
Average load projected to pontoon installation phase	15012319.52	17525876.96	17525876.96	[N/m]
Average load projected to pontoon without traffic but with loss of pontoon	31524059.28	35294395.44	35294395.44	[N/m]

3 STABILITY

3.1 Scenario 1 – Operation without traffic

> *Table 3-1 Stability calculations for operation phase without traffic*

Configuration	1	2	3	
KG	15.17	23.18	30.80	[m]
KB	2.50	2.50	2.50	[m]
I	172163.75	203414.06	233652.40	[m^4]
V	3325.49	3979.40	4619.90	[m^3]
BM	51.77	51.12	50.58	[m]
KM	54.27	53.62	53.08	[m]
GM	**39.10**	**30.44**	**22.27**	**[m]**

3.2 Scenario 2 – Operation with traffic

> *Table 3-2 Stability calculations for operation phase with traffic*

Configuration	1	2	3	
Increase draft due to traffic	0.53	0.44	0.38	[m]
KG	15.64	24.08	32.14	[m]
KB	2.76	2.72	2.69	[m]
I	172163.75	203414.06	233652.40	[m^4]
V	3677.88	4331.79	4972.29	[m^3]
BM	46.81	46.96	46.99	[m]

KM	49.58	49.68	49.68	[m]
GM	**33.94**	**25.60**	**17.54**	**[m]**

3.3 Scenario 3 – Installation phase

> *Tabell 3-1 Stability calculations for the installation phase.*

Configuration	**1**	**2**	**3**	
Decrease draft due to no equipment and asphalt	-0.90	-0.75	-0.65	[m]
KG	14.11	21.26	28.01	[m]
KB	2.05	2.12	2.18	[m]
I	172163.75	203414.06	233652.40	[m^4]
V	2728.41	3382.33	4022.83	[m^3]
BM	63.10	60.14	58.08	[m]
KM	65.15	62.27	60.26	[m]
GM	**51.04**	**41.00**	**32.25**	**[m]**

3.4 Scenario 4 – Loss of single pontoon

Basically, we extract one of the pontoons from the bridge. This is a very conservative approach and goes far beyond any scenarios in the design basis. The load span related to a pontoon increases from 120m to 180m which of course decreases the stability.

> *Tabell 3-2 Stability calculations for the installation phase.*

Configuration	1	2	3	
Increase draft due to loss off pontoon	1.76	1.74	1.60	[m]
KG	16.31	25.67	34.51	[m]
KB	3.38	3.37	3.30	[m]
I	172163.75	203414.06	233652.40	[m^4]
V	4498.99	5364.10	6101.18	[m^3]
BM	38.27	37.92	38.30	[m]
KM	41.65	41.29	41.60	[m]
GM	**25.34**	**15.62**	**7.09**	**[m]**

4 CONCLUSION

All sections of the bridge shows good global stability for all four scenarios presented. The loss of pontoon case for the highest part of the bridge produces the lowest stability (GM=7.1), but still here, the stability is very good.

For any normal circumstance the GM-factor is beyond 17m.

A further investigation finding the RZ-curve (Curve showing the restoring moment for various tilt angles) could have been done, but is found unnecessary at this stage due to the high GM factor for all investigated scenarios.

All values have been extracted from K12 – model 27, found on interactive.olavolsen.no [1]

5 REFERENCES

[1] Olav Olsen, Norconsult, olavolsen.interactive.no; Bjørnafjorden phase 5, Oslo, 2019.

[2] Håndbok N400 , «Bruprosjektering,» Statens vegvesen Vegdirektoratet, 2015.

[3] SBJ-32-C4-SVV-90-BA-001, «Design Basis Bjørnafjorden floating bridges,» Statens Vegvesen, 2018.

[4] NS-EN 1993-1-1:2005+A1:2014+NA:2015, «Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings,» Standard Norge, 2005.