Appendix to report:

SBJ-33-C5-OON-22-RE-013-APPD

K12 - SHIP IMPACT, GLOBAL ASSESSMENT

Appendix title:

APPENDIX D – POST IMPACT EVALUATIONS

Contract no:	18/91094
Project number:	5187772/12777
Document number:	SBJ-33-C5-OON-22-RE-013-AppD
Date:	15.08.2019
Revision:	0
Number of pages:	22
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CONCEPT DEVELOPMENT FLOATING BRIDGE E39 BJØRNAFJORDEN

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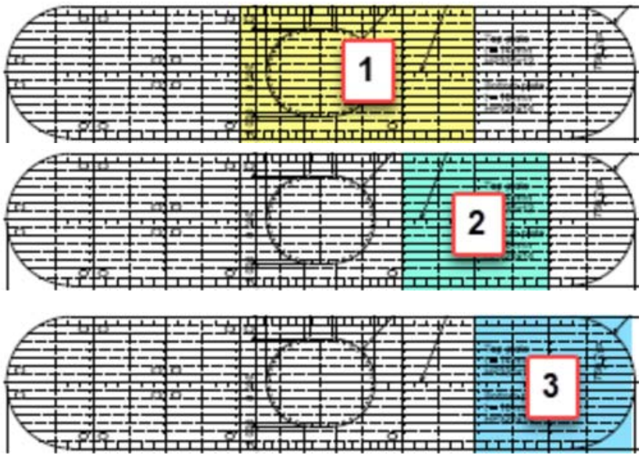
D.1 Pontoon post impact evaluations

There has been performed considerations of the post impact properties of the pontoons. The given scenario is 8,5-13 m indentation between ship and pontoon, see Table 6-2, which theoretically could lead to water filling of four compartments.

The considerations done are simplified and conservative.

There has been considered three different impact scenarios for all three pontoons:



Change in draft

The change in draft is iterated using the global model in Abaqus. When the changed buoyancy force in Abaqus (given as input) corresponds with the new draft (result of analysis) the new draft is found. The draft is as follows:

Bouyancy data	**Pontoons high bridge**	**Pontoons ramp and anchors**	**Pontoons low bridge**
Water plane area undamaged pontoon	924.0	795.9	665.1
Bouyancy force in Abaqus model	4.63E+07	3.70E+07	3.36E+07
	(pont 3)	*(pont 12)*	*(pont 20)*
Damage state 1			
Reduction factor bouyancy	0.60	0.60	0.61
Damaged water plane stiffness [N/m]	5.57E+06	4.83E+06	4.06E+06
Loss in bouyancy force same draft [N]	1.85E+07	1.47E+07	1.32E+07
U3 step-1 [m]	-0.08	0.04	0.00
U3 step damaged pontoon [m]	-1.38	-1.15	-1.15
Increased draft [m]	1.31	1.19	1.15
Extra bouyancy from increased draft [N]	7.13E+06	5.64E+06	4.58E+06
Updated loss of bouyancy [N]	1.14E+07	9.02E+06	8.59E+06

Post impact properties pontoons

The three chosen scenarios give post-impact pontoon properties as shown below:

Pontoon property	Damage scenario	Pontoons high bridge	Pontoons ramp and anchors	Pontoons low bridge
Pontoon width [m]		17,0	14,5	12,0
Water plane vertical stiffness (heave), undamaged [MN/m]		9,3	8,0	6,7
Weak axis rotation (local roll), undamaged [MNm/rad]		192,1	123,4	72,4
Strong axis rotation (local pitch), undamaged [MNm/rad]		2351,6	2049,3	1734,8
Water plane vertical stiffness (heave), damaged [MN/m]	Scenario 1	5,6	4,8	4.1
	Scenario 2	7,0	6,0	5.1
	Scenario 3	7,1	6,1	5.1
Remaining water plane vertical stiffness (compared to undamaged state)	Scenario 1	60 %	60 %	61 %
	Scenario 2	75 %	75 %	75 %
	Scenario 3	76 %	76 %	76 %
Weak axis rotation stiffness (local roll), damaged state [MNm/rad]	Scenario 1	115,2	74,5	44.0
	Scenario 2	144,3	93,1	54.7
	Scenario 3	146,4	93,8	54.8
Strong axis rotation stiffness (local pitch) [MNm/rad]	Scenario 1	2162,7	1888,2	1601.5
	Scenario 2	1848,1	1619,9	1379.4
	Scenario 3	1331,8	1162,3	986.4
Remaining strong axis rotation stiffness (compared to undamaged state)	Scenario 1	92 %	92 %	92 %
	Scenario 2	79 %	79 %	80 %
	Scenario 3	57 %	57 %	57 %
Buoyancy eccentricity moment [MNm]	Scenario 1	79,2	66,2	54.5
	Scenario 2	207,4	173,6	142.7
	Scenario 3	292,7	250,0	209.7
Maximum theoretical local pitch rotation (overestimated) [deg]	Scenario 1	2,1	2,0	2.0
	Scenario 2	6,4	6,2	6.1
	Scenario 3	12,6	12,5	12.5
Corresponding maximum static change in draft at pontoon ends (free-floating body - overestimated) +/- [m]	Scenario 1	1,1	1,0	1.0
	Scenario 2	3,2	3,2	3.1
	Scenario 3	6,4	6,3	6.3
Maximum static change in draft at pontoon ends from FE-model, see Appendix D section D.2, +/- [m]		1,8	1,6	1,3

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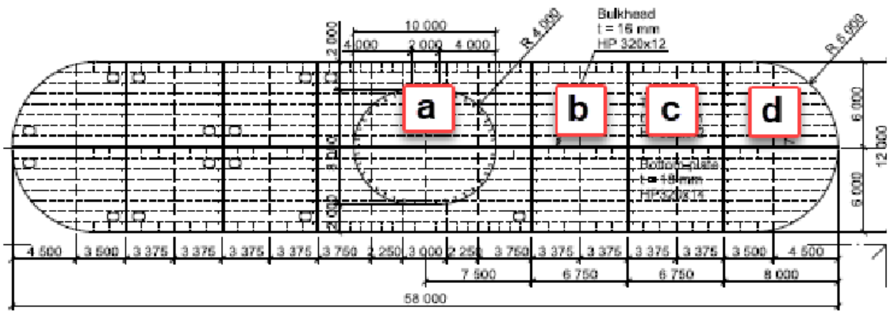
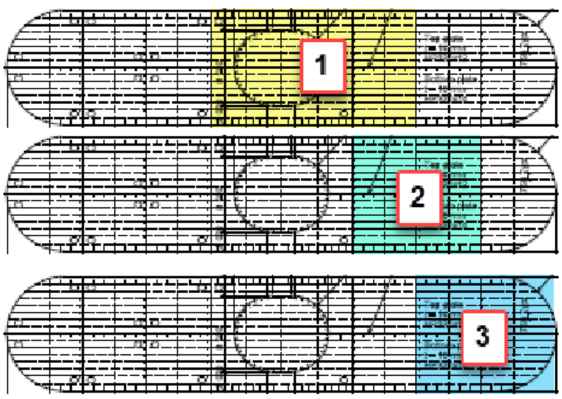
Post impact evaluations - pontoon properties (damaged)

Geometry K12-020 (120 m span, wamit 54, 55 and 56)



Given maximum intendation of 8.5 m at pontoon impact, there is a possibility of waterfilling of four compartments. This gives three possible combinations of waterfilled compartments:

Possible pontoon water fillings:



Chosen scenario: comb := 1

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Geometry

Pontoon with: $w_p := 17m$

Pontoon length: $l_p := 58m$

Pontoon height: $h_p := 9m$

Pontoon draft (expected): $d_p := 5m$

Radius ends: $r_p := \frac{w_p}{2} = 8.5 \cdot m$

Pontoon area (plane): $A_p := w_p \cdot (l_p - 2 \cdot r_p) + \pi \cdot r_p^2 = 924 \cdot m^2$

Compartments:

Compartment lengths:

$l_a := 15m$

$l_b := 6.75m$

$l_c := 6.75m$

$l_d := 8m$

Compartment areas (plane):

$A_a := \frac{w_p}{2} \cdot l_a = 127.5 \cdot m^2$

$A_b := \frac{w_p}{2} \cdot l_b = 57.4 \cdot m^2$

$A_c := \frac{w_p}{2} \cdot l_c = 57.4 \cdot m^2$

$A_d := 0.5 \left[w_p \cdot (l_d - r_p) + \frac{\pi \cdot r_p^2}{2} \right] = 52.5 \cdot m^2$

Water filled area:

$A_{w.1} := 2 \cdot (A_a + A_b) = 369.8 \cdot m^2$ $\quad l_{w.1} := l_a + l_b = 21.8 \cdot m$

$A_{w.2} := 2 \cdot (A_b + A_c) = 229.5 \cdot m^2$ $\quad l_{w.2} := l_b + l_c = 13.5 \cdot m$

$A_{w.3} := 2 \cdot (A_c + A_d) = 219.7 \cdot m^2$ $\quad l_{w.3} := l_c + l_d = 14.8 \cdot m$

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Distance to center waterfilled area:

$$d_{w.1} := \frac{l_a + l_b}{2} - \frac{l_a}{2} = 3.4 \cdot m$$

$$d_{w.2} := \frac{l_a}{2} + \frac{l_b + l_c}{2} = 14.3 \cdot m$$

$$d_{w.3} := \frac{l_a}{2} + l_b + l_c = 21 \cdot m$$

Bouyancy center:

$$a_{w.1} := \frac{A_{w.1}}{A_p - A_{w.1}} \cdot d_{w.1} = 2.3 \cdot m$$

; approximately

$$a_{w.2} := \frac{A_{w.2}}{A_p - A_{w.2}} \cdot d_{w.2} = 4.7 \cdot m$$

$$a_{w.3} := \frac{A_{w.3}}{A_p - A_{w.3}} \cdot d_{w.3} = 6.6 \cdot m$$

$$A_w := \left| \begin{array}{l} A_{w.1} \text{ if } comb = 1 \\ A_{w.2} \text{ if } comb = 2 \\ A_{w.3} \text{ if } comb = 3 \end{array} \right. = 369.8 \cdot m^2$$

$$a_w := \left| \begin{array}{l} a_{w.1} \text{ if } comb = 1 \\ a_{w.2} \text{ if } comb = 2 \\ a_{w.3} \text{ if } comb = 3 \end{array} \right. = 2.3 \cdot m$$

$$l_w := \left| \begin{array}{l} l_{w.1} \text{ if } comb = 1 \\ l_{w.2} \text{ if } comb = 2 \\ l_{w.3} \text{ if } comb = 3 \end{array} \right. = 21.8 \cdot m$$

$$d_w := \left| \begin{array}{l} d_{w.1} \text{ if } comb = 1 \\ d_{w.2} \text{ if } comb = 2 \\ d_{w.3} \text{ if } comb = 3 \end{array} \right. = 3.4 \cdot m$$

Summary chosen pontoon and scenario

Pontoon width: $w_p = 17 \cdot m$

Chosen scenario: $comb = 1$

Water plane area filled compartm. $A_w = 369.8 \cdot m^2$

Distance to center waterfilled area: $d_w = 3.4 \cdot m$

Length damaged zone $l_w = 21.8 \cdot m$

Disance to buoyancy center: $a_w = 2.3 \cdot m$

Material

Water density: $\gamma_w := 1025 \frac{kg}{m^3} \cdot g = 10.05 \cdot \frac{kN}{m^3}$

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Damaged pontoonestimates:

$comb = 1$

$w_p = 17m$

Intact area damaged pontoon: $A_{res.p} := A_p - A_w = 554.2 \cdot m^2$

Reduction factor damaged pontoon: $\boxed{\eta_d := \frac{A_{res.p}}{A_p} = 0.6}$

Vertical water plane stiffness, undamaged: $K_{33} := A_p \cdot \gamma_w = 9.288 \cdot \frac{MN}{m}$

Vertical water plane stiffness, damaged: $\boxed{K_{33.d} := K_{33} \cdot \eta_d = 5.571 \cdot \frac{MN}{m}}$

Expected bouyancy normal conditions: $F_{b.norm} := A_p \cdot d_p \cdot \gamma_w = 46.4 \cdot MN$

Initial loss of bouyancy: $\Delta_{F.b.d} := d_p \cdot (K_{33} - K_{33.d}) = 18.6 \cdot MN$ $d_p = 5 \cdot m$

Additional pontoon draft: $\boxed{\Delta d_p := 1.31m}$ *; from Abaqus*

New buoyancy: $\boxed{F_{b.d} := K_{33.d} \cdot (d_p + \Delta d_p) = 35.2 \cdot MN}$

Bouyancy moment: $\boxed{M_{b.d} := F_{b.d} \cdot a_w = 79.2 \cdot MN \cdot m}$ *; to Abaqus*

Max bouyancy undamaged pontoon: $F_{b.max} := A_p \cdot h_p \cdot \gamma_w = 83.6 \cdot MN$

Max bouyancy damaged pontoon: $F_{b.max.d} := A_{res.p} \cdot h_p \cdot \gamma_w = 50.1 \cdot MN$

Maximum bending moment from bouyancy damaged pontoon: $M_{b.max.d} := F_{b.max.d} \cdot a_w = 112.9 \cdot MN \cdot m$

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Approximately water plane rotational stiffnesses:

Weak axis (local roll), undamaged:

$$K_{44.p} := \gamma_w \frac{1}{12} \cdot w_p^3 \cdot \left(l_p - 2\frac{2}{3} r_p\right) = 192.1 \cdot \frac{MN \cdot m}{rad}$$

Weak axis (local roll), damaged:

$$\boxed{K_{44.p.d} := \eta_d \cdot K_{44.p} = 115.2 \cdot \frac{MN \cdot m}{rad}}$$

Strong axis (local pitch), undamaged:

$$K_{55.p} := \gamma_w \cdot \left[\frac{1}{12} \cdot w_p \cdot \left(l_p\right)^3 - 2\left(2 \cdot r_p^2 - \frac{\pi \cdot r_p^2}{2}\right) \cdot \left(\frac{l_p}{2} - \frac{r_p}{3}\right)^2\right]$$

$$K_{55.p} = 2351.6 \frac{MN \cdot m}{rad}$$

Strong axis (local pitch), damaged:

$$\boxed{K_{55.p.d} := K_{55.p} - \gamma_w \cdot \left(\frac{1}{12} \cdot w_p \cdot l_w^3 + A_w \cdot d_w^2\right) = 2162.7 \cdot \frac{MN \cdot m}{rad}}$$

Remaining local pitch stiffness:

$$\boxed{\eta_{d.K55} := \frac{K_{55.p.d}}{K_{55.p}} = 0.9}$$

Theoretical local pitch rotation:

$$\boxed{\varphi_d := \frac{M_{b.d}}{K_{55.p.d}} = 2.1 \deg}$$

; too conservative as it does not take into account the change in buoyancy center due to local ptich rotation

Theoretical vertical displacement of pontoon end due to local pitch:

$$\boxed{U_{z.max.pontoon\_end} := \varphi_d \cdot \frac{l_p}{2} = 1.1\,m}$$

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Calculations of pontoon properties, pontoon axis 3, scenario 3 (eccentric impact):

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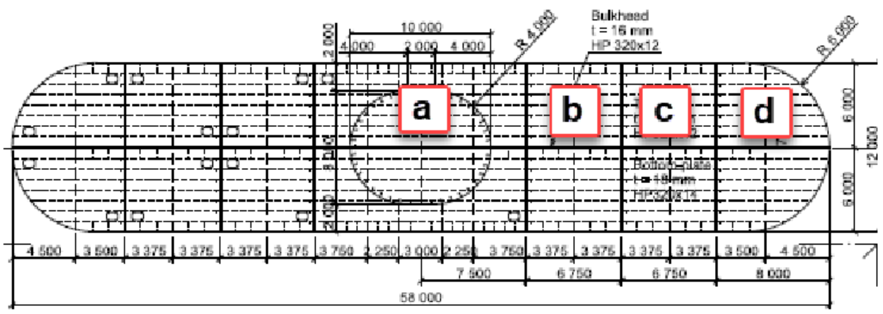
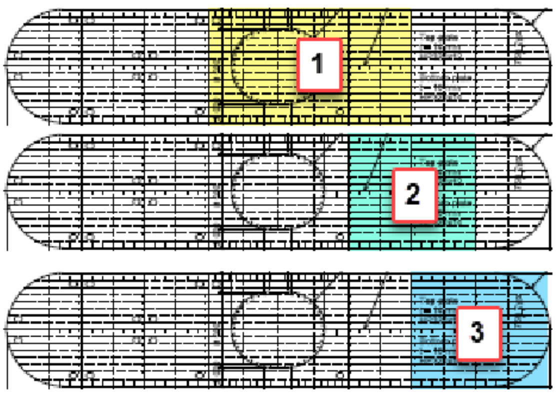
Post impact evaluations - pontoon properties (damaged)

Geometry K12-020 (120 m span, wamit 54, 55 and 56)



Given maximum intendation of 8.5 m at pontoon impact, there is a possibility of waterfilling of four compartments. This gives three possible combinations of waterfilled compartments:

Possible pontoon water fillings:



Chosen scenario: $comb := 3$

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Geometry

Pontoon with: $\boxed{w_p := 17m}$

Pontoon length: $\boxed{l_p := 58m}$

Pontoon height: $\boxed{h_p := 9m}$

Pontoon draft (expected): $\boxed{d_p := 5m}$

Radius ends: $r_p := \frac{w_p}{2} = 8.5 \cdot m$

Pontoon area (plane): $A_p := w_p \cdot (l_p - 2 \cdot r_p) + \pi \cdot r_p^{\,2} = 924 \cdot m^2$

Compartments:

Compartment lengths:

$\boxed{l_a := 15m}$

$\boxed{l_b := 6.75m}$

$\boxed{l_c := 6.75m}$

$\boxed{l_d := 8m}$

Compartment areas (plane):

$$A_a := \frac{w_p}{2} \cdot l_a = 127.5 \cdot m^2$$

$$A_b := \frac{w_p}{2} \cdot l_b = 57.4 \cdot m^2$$

$$A_c := \frac{w_p}{2} \cdot l_c = 57.4 \cdot m^2$$

$$A_d := 0.5 \left[w_p \cdot (l_d - r_p) + \frac{\pi \cdot r_p^{\,2}}{2} \right] = 52.5 \cdot m^2$$

Water filled area:

$\boxed{A_{w.1} := 2 \cdot (A_a + A_b) = 369.8 \cdot m^2}$ $\quad l_{w.1} := l_a + l_b = 21.8 \cdot m$

$\boxed{A_{w.2} := 2 \cdot (A_b + A_c) = 229.5 \cdot m^2}$ $\quad l_{w.2} := l_b + l_c = 13.5 \cdot m$

$\boxed{A_{w.3} := 2 \cdot (A_c + A_d) = 219.7 \cdot m^2}$ $\quad l_{w.3} := l_c + l_d = 14.8 \cdot m$

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Distance to center waterfilled area:

$$d_{w.1} := \frac{l_a + l_b}{2} - \frac{l_a}{2} = 3.4 \cdot m$$

$$d_{w.2} := \frac{l_a}{2} + \frac{l_b + l_c}{2} = 14.3 \cdot m$$

$$d_{w.3} := \frac{l_a}{2} + l_b + l_c = 21 \cdot m$$

Bouyancy center: $a_{w.1} := \frac{A_{w.1}}{A_p - A_{w.1}} \cdot d_{w.1} = 2.3 \cdot m$ *; approximately*

$$a_{w.2} := \frac{A_{w.2}}{A_p - A_{w.2}} \cdot d_{w.2} = 4.7 \cdot m$$

$$a_{w.3} := \frac{A_{w.3}}{A_p - A_{w.3}} \cdot d_{w.3} = 6.6 \cdot m$$

$$A_w := \left| \begin{array}{ll} A_{w.1} & \text{if } comb = 1 \\ A_{w.2} & \text{if } comb = 2 \\ A_{w.3} & \text{if } comb = 3 \end{array} \right. = 219.7 \cdot m^2$$

$$a_w := \left| \begin{array}{ll} a_{w.1} & \text{if } comb = 1 \\ a_{w.2} & \text{if } comb = 2 \\ a_{w.3} & \text{if } comb = 3 \end{array} \right. = 6.6 \cdot m$$

$$l_w := \left| \begin{array}{ll} l_{w.1} & \text{if } comb = 1 \\ l_{w.2} & \text{if } comb = 2 \\ l_{w.3} & \text{if } comb = 3 \end{array} \right. = 14.8 \cdot m$$

$$d_w := \left| \begin{array}{ll} d_{w.1} & \text{if } comb = 1 \\ d_{w.2} & \text{if } comb = 2 \\ d_{w.3} & \text{if } comb = 3 \end{array} \right. = 21 \cdot m$$

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Summary chosen pontoon and scenario

Pontoon width: $w_p = 17 \cdot m$

Chosen scenario: $comb = 3$

Water plane area filled compartm. $A_w = 219.7 \cdot m^2$

Distance to center waterfilled area: $d_w = 21 \cdot m$

Length damaged zone $l_w = 14.8 \cdot m$

Disance to buoyancy center: $a_w = 6.6 \cdot m$

Material

Water density: $\gamma_w := 1025 \frac{kg}{m^3} \cdot g = 10.05 \cdot \frac{kN}{m^3}$

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Damaged pontoonestimates:

$comb = 3$

$w_p = 17m$

Intact area damaged pontoon: $A_{res.p} := A_p - A_w = 704.2 \cdot m^2$

Reduction factor damaged pontoon: $\eta_d := \dfrac{A_{res.p}}{A_p} = 0.76$

Vertical water plane stiffness, undamaged: $K_{33} := A_p \cdot \gamma_w = 9.288 \cdot \dfrac{MN}{m}$

Vertical water plane stiffness, damaged: $K_{33.d} := K_{33} \cdot \eta_d = 7.079 \cdot \dfrac{MN}{m}$

Expected bouyancy normal conditions: $F_{b.norm} := A_p \cdot d_p \cdot \gamma_w = 46.4 \cdot MN$

Initial loss of bouyancy: $\Delta_{F.b.d} := d_p \cdot (K_{33} - K_{33.d}) = 11 \cdot MN$ $\qquad d_p = 5 \cdot m$

Additional pontoon draft: $\Delta d_p := 1.31m$ *; from Abaqus*

New buoyancy: $F_{b.d} := K_{33.d} \cdot (d_p + \Delta d_p) = 44.7 \cdot MN$

Bouyancy moment: $M_{b.d} := F_{b.d} \cdot a_w = 292.7 \cdot MN \cdot m$ *; to Abaqus*

Max bouyancy undamaged pontoon: $F_{b.max} := A_p \cdot h_p \cdot \gamma_w = 83.6 \cdot MN$

Max bouyancy damaged pontoon: $F_{b.max.d} := A_{res.p} \cdot h_p \cdot \gamma_w = 63.7 \cdot MN$

Maximum bending moment from bouyancy damaged pontoon: $M_{b.max.d} := F_{b.max.d} \cdot a_w = 417.5 \cdot MN \cdot m$

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Approximately water plane rotational stiffnesses:

Weak axis (local roll), undamaged:

$$K_{44.p} := \gamma_w \frac{1}{12} \cdot w_p^3 \cdot \left(l_p - 2\frac{2}{3} r_p\right) = 192.1 \cdot \frac{MN \cdot m}{rad}$$

Weak axis (local roll), damaged:

$$\boxed{K_{44.p.d} := \eta_d \cdot K_{44.p} = 146.4 \cdot \frac{MN \cdot m}{rad}}$$

Strong axis (local pitch), undamaged:

$$K_{55.p} := \gamma_w \cdot \left[\frac{1}{12} \cdot w_p \cdot \left(l_p\right)^3 - 2\left(2 \cdot r_p^2 - \frac{\pi \cdot r_p^2}{2}\right) \cdot \left(\frac{l_p}{2} - \frac{r_p}{3}\right)^2\right]$$

$$K_{55.p} = 2351.6 \frac{MN \cdot m}{rad}$$

Strong axis (local pitch), damaged:

$$\boxed{K_{55.p.d} := K_{55.p} - \gamma_w \cdot \left(\frac{1}{12} \cdot w_p \cdot l_w^3 + A_w \cdot d_w^2\right) = 1331.8 \cdot \frac{MN \cdot m}{rad}}$$

Remaining local pitch stiffness:

$$\boxed{\eta_{d.K55} := \frac{K_{55.p.d}}{K_{55.p}} = 0.6}$$

Theoretical local pitch rotation:

$$\boxed{\varphi_d := \frac{M_{b.d}}{K_{55.p.d}} = 12.6 deg}$$

; too conservative as it does not take into account the change in buoyancy center due to local ptich rotation

Theoretical vertical displacement of pontoon end due to local pitch:

$$\boxed{U_{z.max.pontoon\_end} := \varphi_d \cdot \frac{l_p}{2} = 6.4 m}$$

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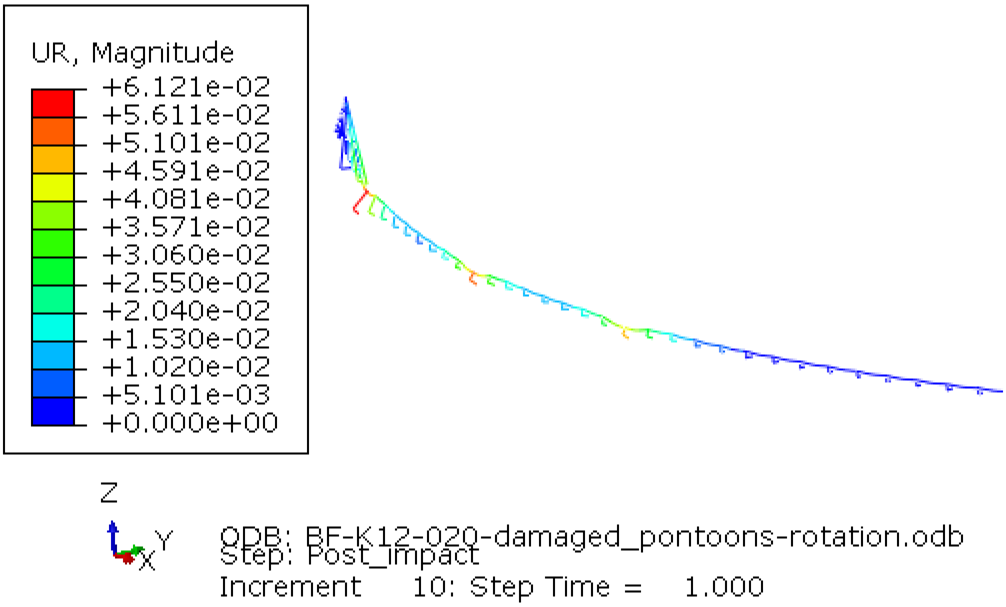
C.1 Post-impact static state from FE-model

There has been performed a control of the permanent rotations in the damaged pontoons due to changed rotational water plane stiffness and the offset buoyancy center. Only scenario 3 has been evaluated as this is the extreme case. Updated water plane stiffnesses, buoyancy forces and -moments has been set on three pontoons on the global model: axis 3, 12 and 20.



This gives rotations of pontoon centers and corresponding drafts:

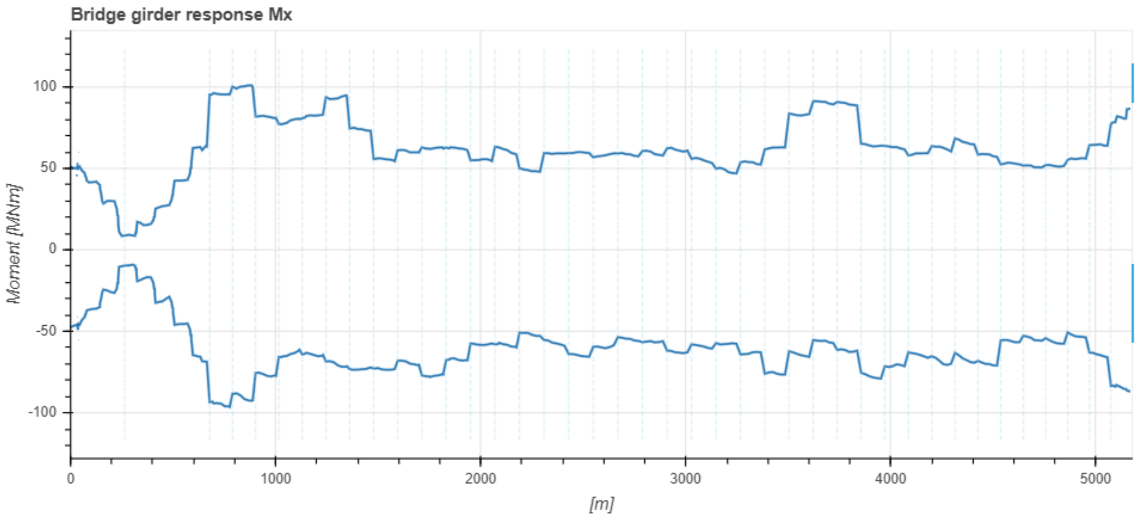
Rotation, center pontoon post impact (from abaqus)	**Pontoons high bridge**	**Pontoons ramp and anchors**	**Pontoons low bridge**
Local UR2 step 1 [rad]	0.00027571	0.000134135	0.00011709
Local UR2 post impact [rad]	0.061141	0.053413	0.0461207
Change in rotation [rad]	0.061	0.053	0.046
Change in rotation [deg]	3.5	3.1	2.6
Change in vertical displacement pontoon ends +/- [m]	1.77	1.55	1.33
Static draft pontoon center [m]	1.3	1.2	1.1
Maximum draft at damaged pontoon end [m]	3.1	2.7	2.5

Which are much lower than the same rotations when evaluating the pontoon alone as a free-floating body. The torsion stiffness of the girder and the interaction between the pontoons are significant.

Together with the static increased draft of 1,31 m (axis 3) the total vertical displacement of the damaged end of the axis 3 pontoon is (1,77+1,31=) 3,1 m. The freeboard is 4 m, but in a 100-years environmental case it must be expected green water on the pontoon deck and overtopping of waves. Both strong axis bending moment capacity of the columns and torsion capacity of the girder are very high and low utilized, so this is not considered critical for the bridge.

Strong axis bending moments for columns are shown in Appendix D section D.3 and are maximum 104 MNm, while the capacity is more than 1500 MNm (S420-steel).

Torsion moments in girder at 100-years environmental load from interactive, load combination 23 [MNm]:



The girder torsion moment capacity is at least 800 MNm (S420-steel) while max torsion moment at 100-years storm is approximately 100 MNm.

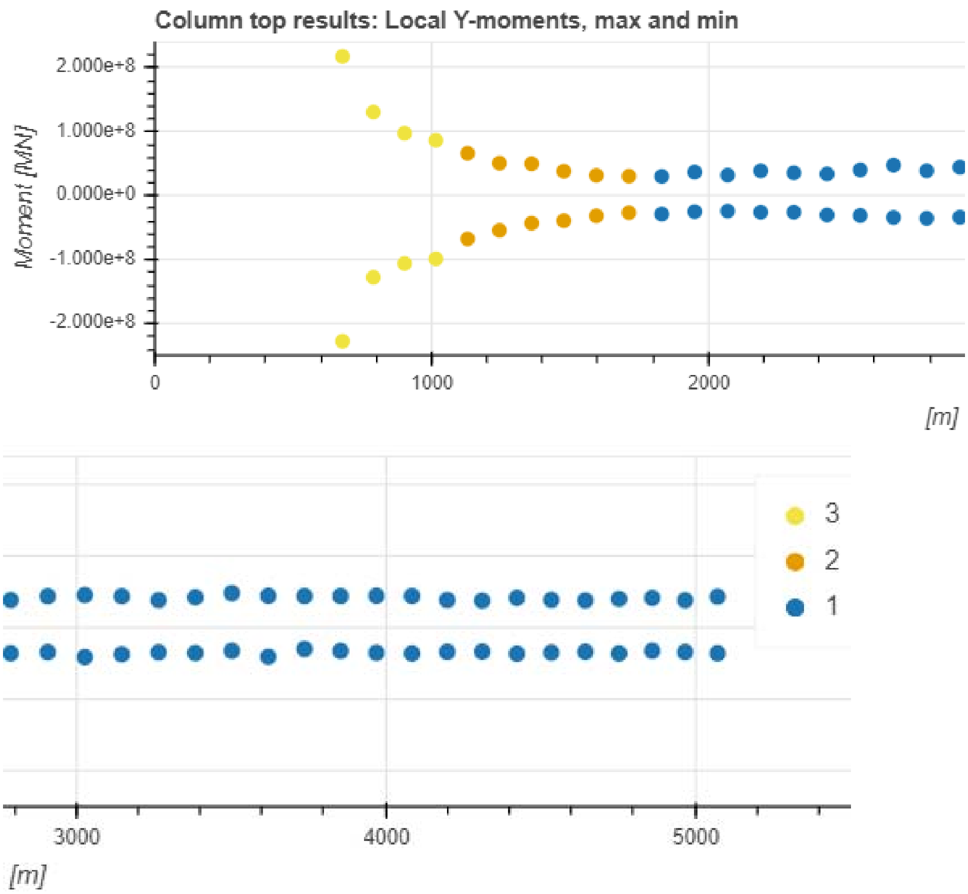
C.2 Local damage in columns due to pontoon impact

Increased loads due to increased draft

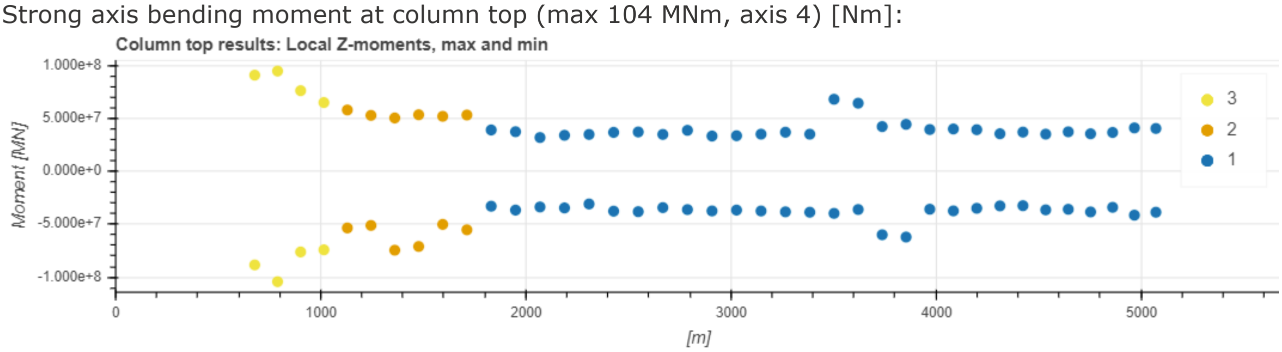
Increased pontoon draft leads to increased forces from current, sway and wind-generated waves. Column forces for the 100-years environmental loading is taken from load combination 23 on interactive, which is a SLS-state but with the same loads and load factors as the ALS-state with load factors of 1,0 on environmental loads and self-weight.

Section forces in column top, load combination 23 (SLS characteristic: 100-years conditions):

Weak axis bending moments in columns (max 227 MNm, axis 3) [Nm]:



Strong axis bending moment at column top (max 104 MNm, axis 4) [Nm]:



Increased loads due to plastic deformations of column top

The 90-degree impacts on axis 3 gives a plastic rotation of the column top, which gives a permanent displacement of 10 m of the pontoon center, see Appendix C part C.4.

Section forces in column due to increased draft

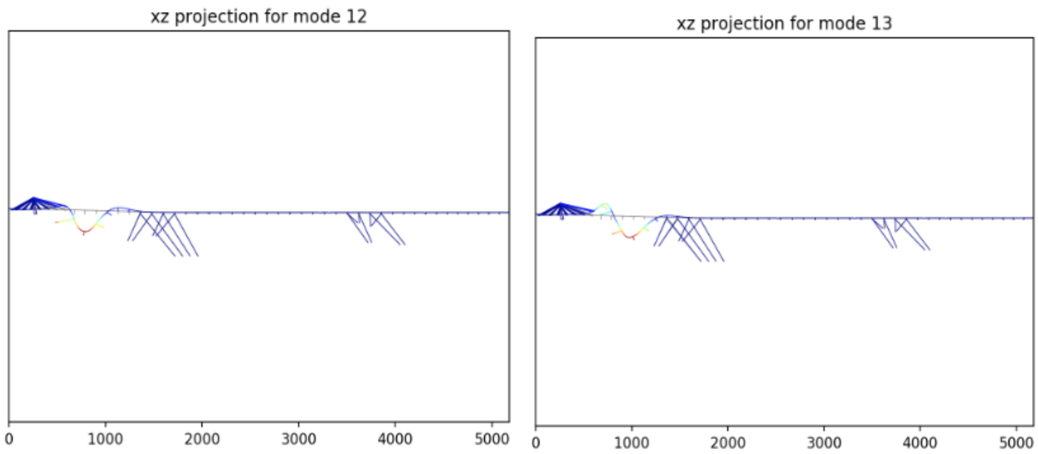
Load combination 23 - SLS 100 years (same as 100 years ALS)			
Section forces columns	**Axis 3 (or 4 if larger)**	**Axis 12**	**Axis 20**
Axial force col bottom (compression) [N]	3.34E+07	2.52E+07	2.52E+07
Weak axis bending moment col top [Nm]	2.27E+08	3.06E+07	4.78E+07
Strong axis bending moment col top [Nm]	1.04E+08	5.52E+07	3.50E+07
Torsion moment column [Nm]	5.34E+07	4.63E+07	4.18E+07
Estimated section forces 100-years storm post impact			
Permanent displacement of pontoon center due to yield in girder-column conection [m]	10	1	1
Increased pontoon draft [m]	1.31	1.19	1.15
Post impact environmental load scale factor (due to increased draft)	1.26	1.24	1.23
Axial force (same as for undamaged) [MN]	33.4	25.2	25.2
Extra bending from eccentricity [MNm]	334.0	25.2	25.2
Weak axis bending moment col top, incl scale factor [MNm]	286.9	37.8	58.8
Total weak axis bending moment [MNm]	620.9	63.0	84.0

The weak axis bending resistance is approximately 800 MNm, see pushover analysis in Appendix F. This means the column remains within the elastic area in the 100-years environmental loading.

As the weak axis second order moment from the buoyancy force is larger than the moment from environmental loads, the post-impact state is depending on the column design. If the weak axis capacity of the column is designed too low, the second order moment from the buoyancy could be higher than the moment resistance.

C.3 Change in dynamic behavior due to increased mass in pontoon

The change of pontoon mass in the axis 3 pontoon due to filling of water will change the modal properties of the bridge. The modes 12 and 13 are pendulum modes where mainly the high bridge is participating. See plots from interactive and structural response analyses [1] in the figure below:



Mode	Frequency [Hz]	Te [s]
10	0.13	7.78
11	0.14	7.12
12	0.15	6.83
13	0.15	6.69

The pendulum modes are mainly trigged by the wind-sea, the sway gives little response on the bridge.

The wind sea is operation for periods lower than 5,5 second, see "Design basis MetOcean_rev_1", [2], while the pendulum modes have eigen periods above 7 seconds in an undamaged state. An increase of the time period for the pendulum modes will not lead to an increase in the loads due to dynamic effects, rather a decrease.

The bridge response is not expected to be affected by increased mass due to water filling of the pontoon.

1 REFERENCES

[1] SBJ-33-C5-OON-22-RE-012-B, «K12 - Structural response analyses,» 2019.

[2] Statens vegvesen, «SBJ-01-C4-SVV-01-BA-001 Design basis MetOcean_rev_1,» 2018.

[3] SBJ-32-C5-OON-22-RE-003-B, «Analysis method,» 2019.

[4] SBJ-33-C5-OON-22-RE-014-B, «K12 - Ship impact, Pontoons and columns,» 2019.