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COMPARATIVE STUDY OF TWO DESIGN VERSIONS OF AN OFF-SHORE BARGE BY OBLIQUE WAVES GLOBAL STRENGTH CRITERIA

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ABSTRACT

The shipbuilding design rules require several criteria for the assessment of any floating structure. For this technical paper, a 23000 t off-shore barge is assessed by oblique waves global strength criteria. Two barge concepts are evaluated, with the main changes of breadth and draught. Focusing on the preliminary analysis that involves the initial concepts of the off-shore barge, the oblique global strength assessment is done by an equivalent 1D beam structural model approach on a significant design wave range. The study of the two off-shore barge concept versions points out their restrictions in operation by global strength preliminary criteria.

Keywords: oblique global strength, design waves, 23000 t off-shore barge design versions.

1. INTRODUCTION

The oblique global strength [1] is analyzed for two design concepts of a 23000 t off-shore barge [2], with the main data in Table 1 and hull lines in Fig.1. The main differences of the two concepts are the breadth and draught.

Table 1. Main data of 23000 t barge [2].

L[m]	189.0	Type:	*B40* (1)	*B50* (2)
H[m]	21.30	Δ[t]	49586.0	56390.0
H_D[m]	1.5-2.0	B[m]	40.0	50.0
ρ[t/m^3]	1.025	d_{aft}[m]	6.586	6.000
g[m/s^2]	9.81	d_m[m]	6.586	6.000
Cargo [t]	23000	d_{fore}[m]	6.586	6.000
Sections	270	μ [deg]	0 –85 (90) (step 5)	
Points	5400	H_w[m]	0–12 (step 1.0)	

The numerical global strength under oblique quasi-static waves is based on a non-linear 1D equivalent beam approach for sink-age, trim and heeling offshore-barge parame-ters, by eigen program code *P_QSW* [3].

The bending, shearing and torsional limit strength criteria are selected according to the DNV [4] shipbuilding rules and are included in the next table. The strength differences between the two concept versions are obtained.

Table 2. DNV [1] Limit strength criteria.

Off-shore barge	*B40* (1)	*B50* (2)
VBM_{adm}[kNm]	3.99E+06	4.99E+06
VSF_{adm}[kN]	7.26E+04	9.07E+04
HBM_{adm}[kNm]	1.40E+06	1.53E+06
HSF_{adm}[kN]	2.31E+04	2.53E+04
MT_{adm}[kNm]	7.77E+05	1.23E+06

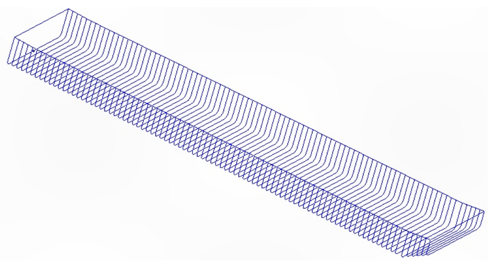


Fig.1. The hull-lines of the 23000 t barge (B40) [2].

2. STRENGTH RESULTS FOR THE OFF-SHORE BARGE B40 (1)

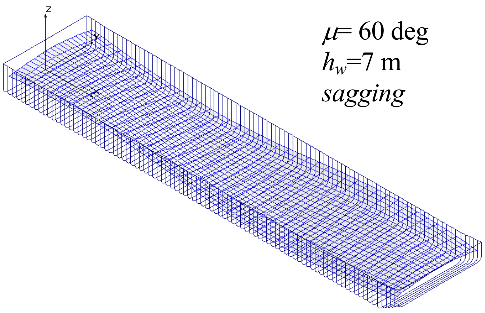
The numerical strength analyses under oblique waves for the off-shore barge B40 (1) lead to the following results:

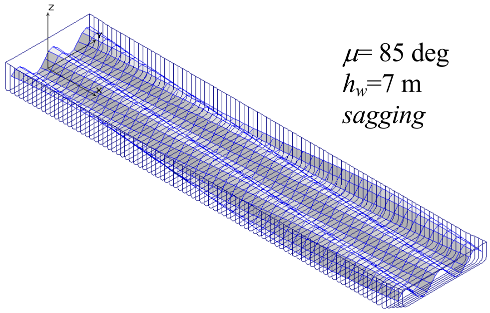
-the sinkage, trim and heeling non-linear barge equilibrium parameters for the selected heading angles μ= 0, 30, 60 and 85 deg, still water and selected equivalent wave height h_w=0, 6, 12 m, sagging and hogging condition, off-shore barge B40 (Table 3);

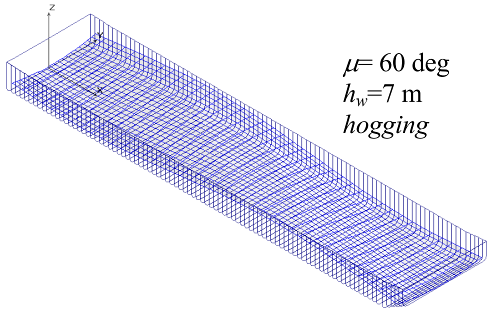
Table 3 Sinkage, trim, heel, Barge B40.

B40	μ[deg] / h_w[m]	0	30	60	85
sinkage [m]	0;sw	6.586	6.586	6.586	6.586
	6;S	6.586	6.586	6.586	6.586
	6;H	6.567	6.571	6.600	6.612
	12;S	6.916	6.916	6.916	6.586
	12;H	6.756	6.786	6.992	6.661
trim [rad]	0;sw	0.00	0.00	0.00	0.00
	6;S	0.00	0.00	0.00	0.00
	6;H	-0.00061	-0.00047	0.00041	0.00079
	12;S	0.00	0.00	0.00	0.00
	12;H	-0.00375	-0.00309	0.00189	0.00131
heel [rad]	0;sw	0.00	0.00	0.00	0.00
	6;S	0.00	0.00	0.00	0.00
	6;H	0.00	-0.00007	-0.00019	0.00
	12;S	0.00	0.00	0.00	0.00
	12;H	0.00	0.00	0.00	0.00

-oblique equivalent quasi-static waves and off-shore barge B40 on equilibrium condition for selected heading angles μ = 60 and 85 deg, sagging and hogging reference wave height h_w=7 m (Fig.2);







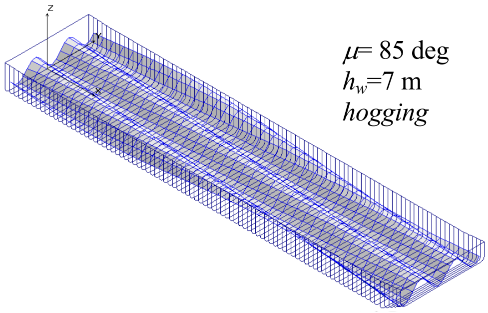
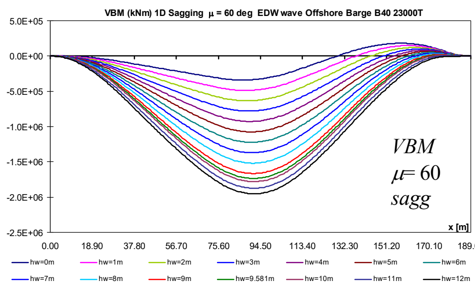
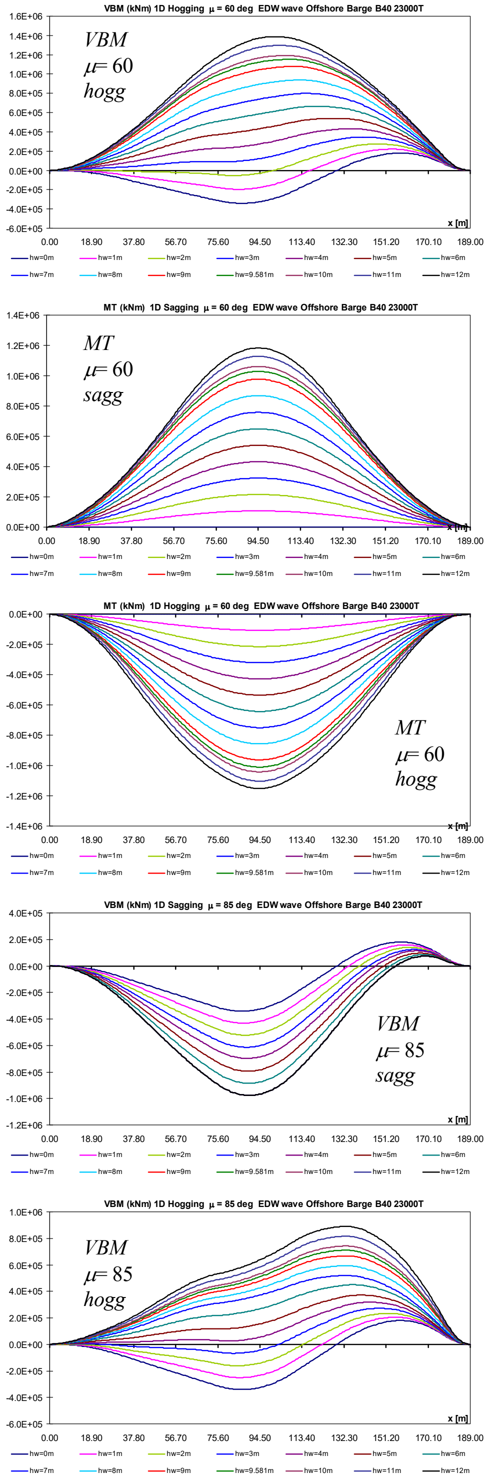


Fig.2 Sagging and hogging oblique waves, μ= 60 and 85 deg, h_w=7 m, Barge B40.

-vertical bending and torsional moments diagrams, for oblique design waves μ = 60 and 85 deg, sagging and hogging, barge B40 (Fig.3);





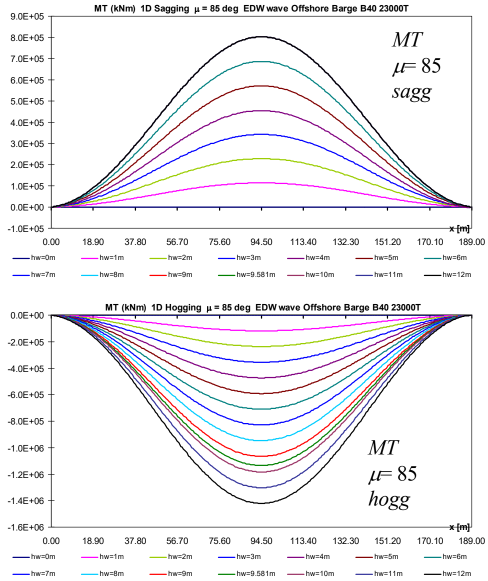


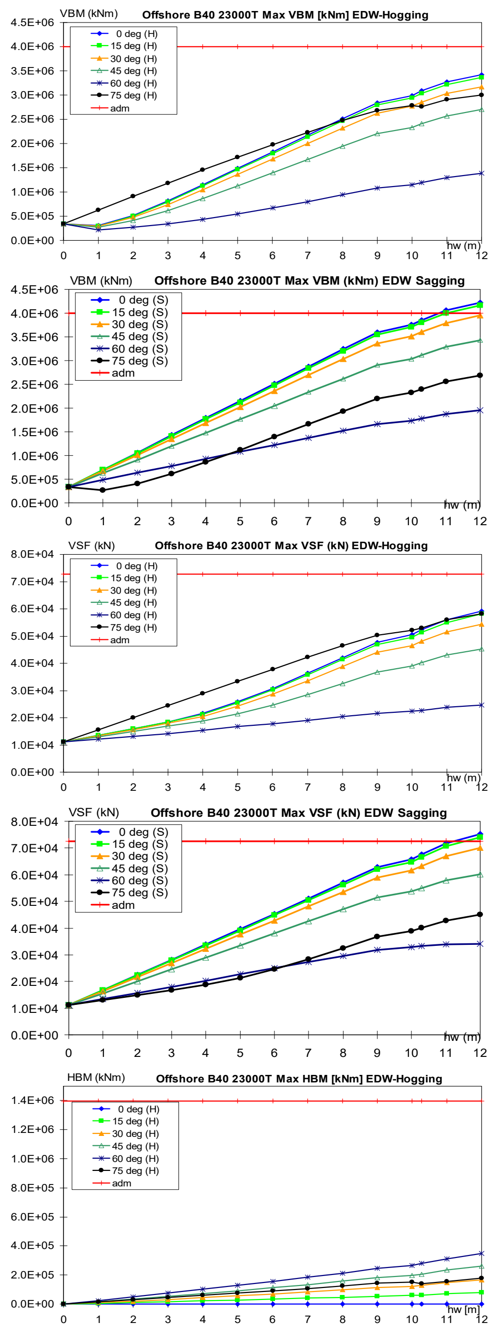
Fig.3 Vertical bending and torsional moments [kNm], $\mu = 60$, 85 deg, sagg, hogg, Barge B40.

-maximum vertical and horizontal bending moments, torsional moment, values for the selected heading angles μ= 0, 30, 60 and 75 deg, still water and selected equivalent wave height h_w=0, 6, 12 m, sagging and hogging, off-shore barge B40 (Table 4);

Table 4 Maximum values *VBM*, *HBM*, *MT*.

B40	μ[deg] / h_w[m]	0	30	60	75
VBM [kNm]	0;sw	3.4E+5	3.4E+5	3.4E+5	3.4E+5
	6;S	2.5E+6	2.4E+6	1.2E+6	1.4E+6
	6;H	1.8E+6	1.7E+6	6.7E+5	2.0E+6
	12;S	4.2E+6	4.0E+6	2.0E+6	2.7E+6
	12;H	3.4E+6	3.2E+6	1.4E+6	3.0E+6
HBM [kNm]	0;sw	0.00	0.00	0.00	0.00
	6;S	0.00	4.8E+4	1.3E+5	1.1E+5
	6;H	0.00	7.0E+4	1.6E+5	9.1E+4
	12;S	0.00	8.8E+4	2.5E+5	2.7E+5
	12;H	0.00	1.7E+5	3.5E+5	1.8E+5
MT [kNm]	0;sw	0.00	0.00	0.00	0.00
	6;S	0.00	2.7E+5	6.5E+5	6.9E+5
	6;H	0.00	2.6E+5	6.4E+5	6.8E+5
	12;S	0.00	4.6E+5	1.2E+6	1.2E+6
	12;H	0.00	4.5E+5	1.2E+6	1.2E+6

- the bending (*VBM*, *HBM*), shearing (*VSF*, *HSF*) and torsional (*MT*) strength criteria by DNV [4] rules (Table 2), using the 1D beam approach assessment for Barge B40 (Fig.4);



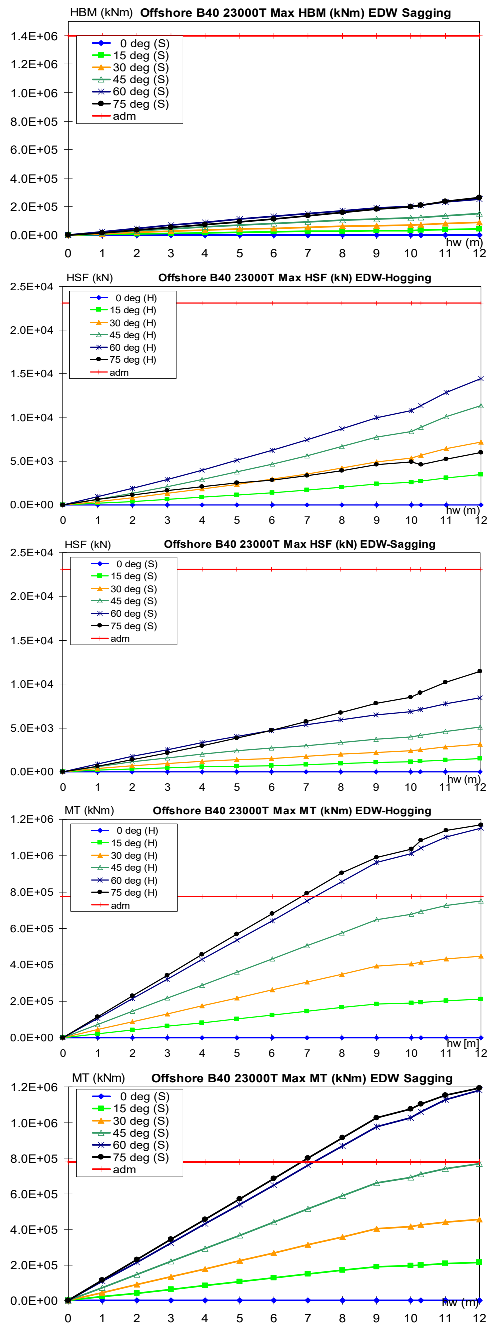


Fig.4 Maximum sectional efforts, Barge B40.

- the freeboard at aft-mid-fore sections, port and starboard sides criteria assessment, using the 1D beam model for Barge B40 (Fig.5).

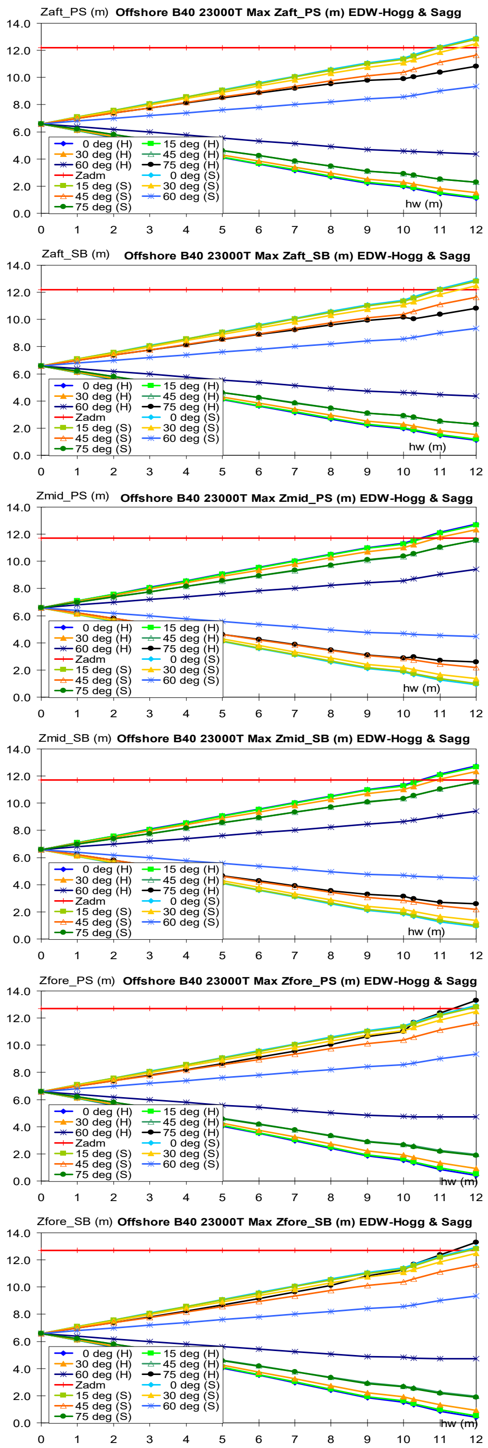


Fig.5 Freeboard assessment, Barge B40.

3. STRENGTH RESULTS FOR THE OFF-SHORE BARGE B50 (2)

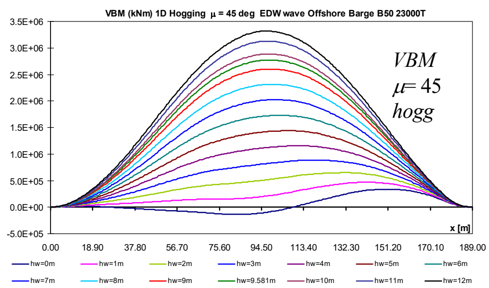
The numerical strength analyses under oblique waves for the off-shore barge B50 (2) lead to the following results:

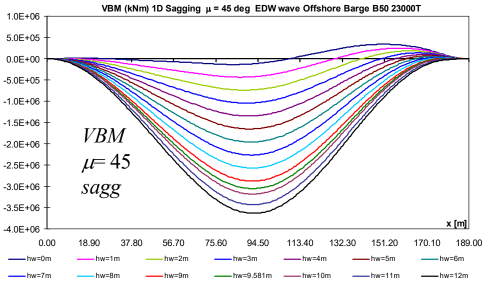
-the sinkage, trim and heeling non-linear barge equilibrium parameters for the selected heading angles μ= 0, 15, 45 and 75 deg, still water and selected equivalent wave height h_w=0, 6, 12 m, sagging and hogging condition, off-shore barge B50 (Table 5);

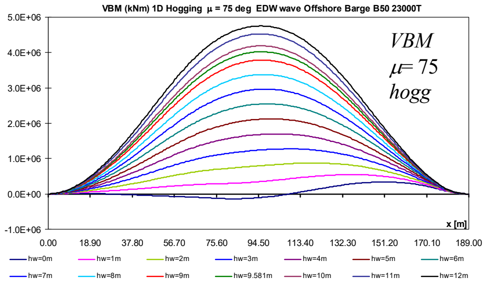
Table 5 Sinkage, trim, heel, Barge B50.

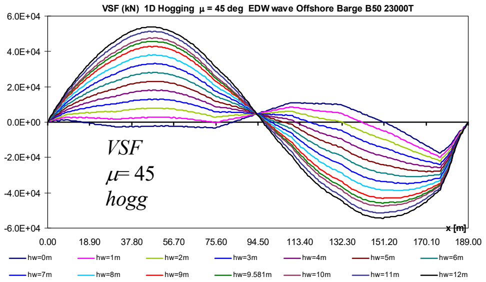
B50	μ[deg] / h_w[m]	0	15	45	75
sinkage [m]	0;sw	6.000	6.000	6.000	6.000
	6;S	6.000	6.000	6.000	5.967
	6;H	5.967	5.969	5.991	6.070
	12;S	6.150	6.150	6.150	6.037
	12;H	5.945	5.953	6.087	6.568
trim [rad]	0;sw	0.00	0.00	0.00	0.00
	6;S	0.00	0.00	0.00	-0.00104
	6;H	-0.00103	-0.00097	-0.00029	0.00216
	12;S	0.00	0.00	0.00	-0.00467
	12;H	-0.00514	-0.00494	-0.00167	0.00701
heel [rad]	0;sw	0.00	0.00	0.00	0.00
	6;S	0.00	0.00	0.00	-0.00001
	6;H	0.00	-0.00005	-0.00014	-0.00141
	12;S	0.00	0.00	0.00	0.00
	12;H	0.00	0.00	0.00	0.00

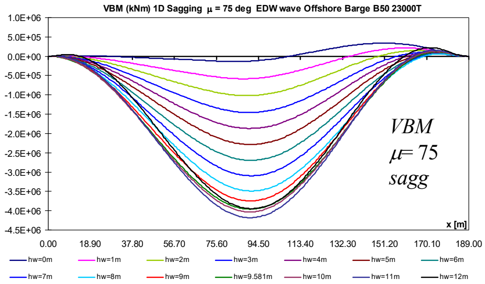
-vertical bending moment, shearing force and torsional moment diagrams, for oblique design waves μ = 45 and 75 deg, sagging and hogging, second design version barge B50 (Fig.6);

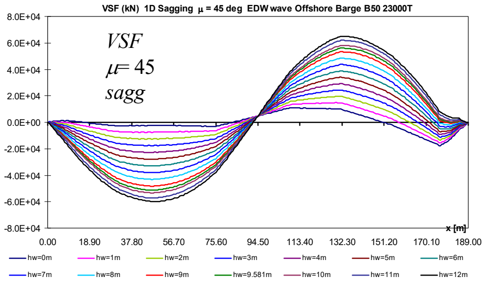


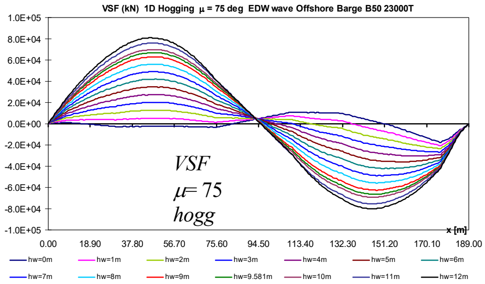

VBM (kNm) 1D Sagging μ = 45 deg EDW wave Offshore Barge B50 23000T
VBM
μ= 45
sagg
x [m]
hw=0m hw=1m hw=2m hw=3m hw=4m hw=5m hw=6m
hw=7m hw=8m hw=9m hw=9.581m hw=10m hw=11m hw=12m

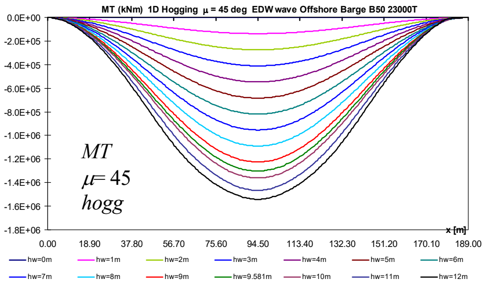

VBM (kNm) 1D Hogging μ = 75 deg EDW wave Offshore Barge B50 23000T
VBM
μ= 75
hogg
x [m]
hw=0m hw=1m hw=2m hw=3m hw=4m hw=5m hw=6m
hw=7m hw=8m hw=9m hw=9.581m hw=10m hw=11m hw=12m

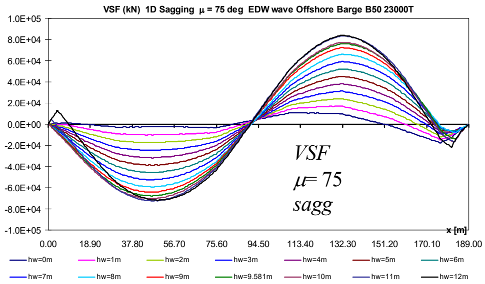

VSF (kN) 1D Hogging μ = 45 deg EDW wave Offshore Barge B50 23000T
VSF
μ= 45
hogg
x [m]
hw=0m hw=1m hw=2m hw=3m hw=4m hw=5m hw=6m
hw=7m hw=8m hw=9m hw=9.581m hw=10m hw=11m hw=12m


VBM (kNm) 1D Sagging μ = 75 deg EDW wave Offshore Barge B50 23000T
VBM
μ= 75
sagg
x [m]
hw=0m hw=1m hw=2m hw=3m hw=4m hw=5m hw=6m
hw=7m hw=8m hw=9m hw=9.581m hw=10m hw=11m hw=12m


VSF (kN) 1D Sagging μ = 45 deg EDW wave Offshore Barge B50 23000T
VSF
μ= 45
sagg
x [m]
hw=0m hw=1m hw=2m hw=3m hw=4m hw=5m hw=6m
hw=7m hw=8m hw=9m hw=9.581m hw=10m hw=11m hw=12m


VSF (kN) 1D Hogging μ = 75 deg EDW wave Offshore Barge B50 23000T
VSF
μ= 75
hogg
x [m]
hw=0m hw=1m hw=2m hw=3m hw=4m hw=5m hw=6m
hw=7m hw=8m hw=9m hw=9.581m hw=10m hw=11m hw=12m


MT (kNm) 1D Hogging μ = 45 deg EDW wave Offshore Barge B50 23000T
MT
μ= 45
hogg
x [m]
hw=0m hw=1m hw=2m hw=3m hw=4m hw=5m hw=6m
hw=7m hw=8m hw=9m hw=9.581m hw=10m hw=11m hw=12m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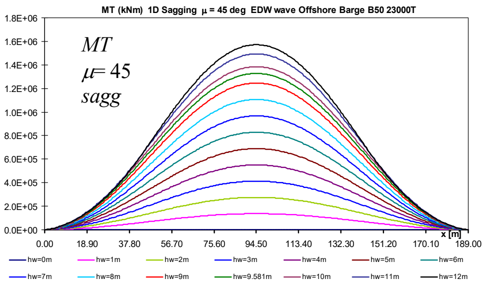
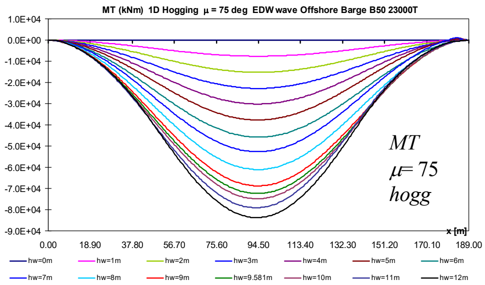
VSF
μ= 75
sagg
x [m]
hw=0m hw=1m hw=2m hw=3m hw=4m hw=5m hw=6m
hw=7m hw=8m hw=9m hw=9.581m hw=10m hw=11m hw=12m


MT (kNm) 1D Sagging μ = 45 deg EDW wave Offshore Barge B50 23000T
MT
μ= 45
sagg
x [m]
hw=0m hw=1m hw=2m hw=3m hw=4m hw=5m hw=6m
hw=7m hw=8m hw=9m hw=9.581m hw=10m hw=11m hw=12m


MT (kNm) 1D Hogging μ = 75 deg EDW wave Offshore Barge B50 23000T
MT
μ= 75
hogg
x [m]
hw=0m hw=1m hw=2m hw=3m hw=4m hw=5m hw=6m
hw=7m hw=8m hw=9m hw=9.581m hw=10m hw=11m hw=12m

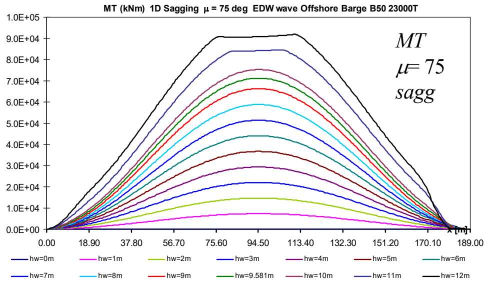


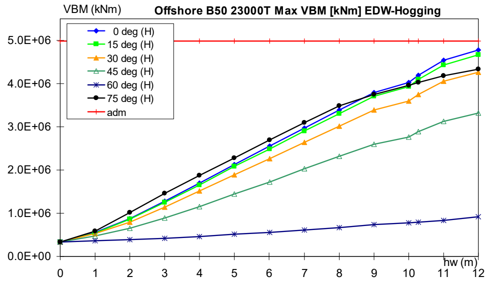
Fig.6 Vertical bending and torsional moments [kNm], vertical shear forces [kN], μ = 45, 75 deg, sagging, hogging, Barge B50.

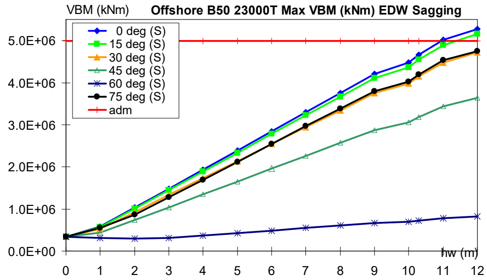
-maximum vertical *VBM* and horizontal *HBM* bending moments, *MT* torsional moment, parameters for the selected heading angles μ= 0, 30, 45 and 60 deg, still water and selected equivalent wave height h_w=0, 6, 12 m, sagging and hogging, second design version offshore Barge B50 (Table 6);

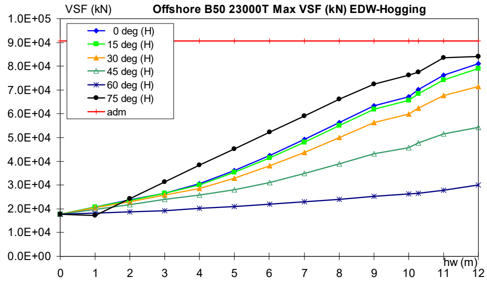
Table 6 Maximum values *VBM*, *HBM*, *MT*.

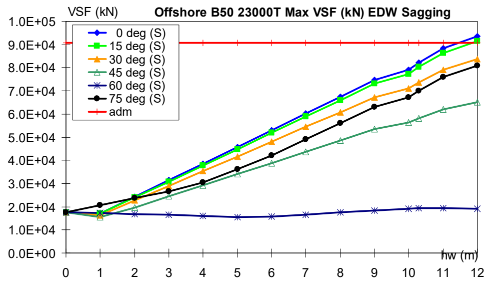
B50	μ[deg] / h_w[m]	0	30	45	60
VBM [kNm]	0;sw	3.4E+5	3.4E+5	3.4E+5	3.4E+5
	6;S	2.8E+6	2.5E+6	2.0E+6	4.9E+5
	6;H	2.6E+6	2.3E+6	1.7E+6	5.6E+5
	12;S	5.3E+6	4.7E+6	3.6E+6	8.2E+5
	12;H	4.8E+6	4.3E+6	3.3E+6	9.2E+5
HBM [kNm]	0;sw	0.00	0.00	0.00	0.00
	6;S	0.00	5.4E+4	9.1E+4	1.4E+5
	6;H	0.00	7.9E+4	1.2E+5	1.5E+5
	12;S	0.00	9.3E+4	1.6E+5	2.7E+5
	12;H	0.00	1.9E+5	2.8E+5	3.2E+5
MT [kNm]	0;sw	0.00	0.00	0.00	0.00
	6;S	0.00	5.2E+5	8.3E+5	1.1E+6
	6;H	0.00	5.1E+5	8.2E+5	1.1E+6
	12;S	0.00	9.6E+5	1.6E+6	2.1E+6
	12;H	0.00	9.3E+5	1.5E+6	2.1E+6

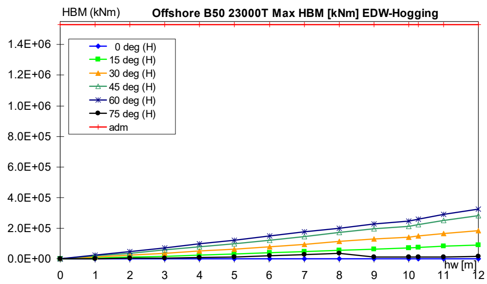
- the vertical *VBM* and horizontal *HBM* bending moments, vertical *VSF* and horizontal *HSF* shearing forces and torsional *MT* moment strength criteria by DNV [4] rules (Table 2), using the 1D beam approach assessment for Barge B50 (Fig.7);











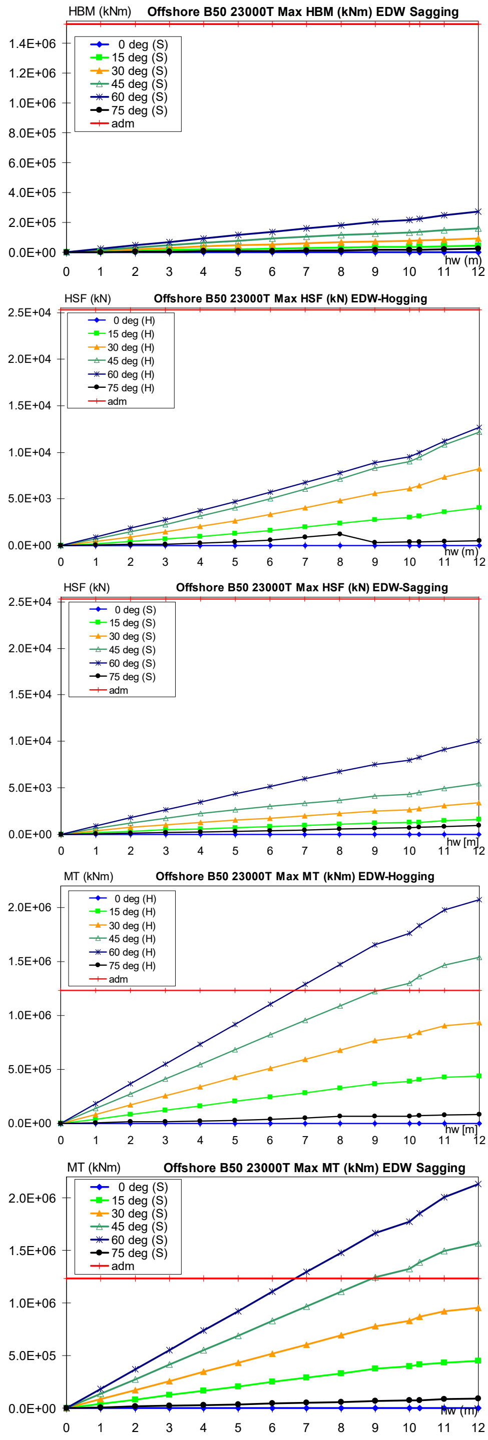
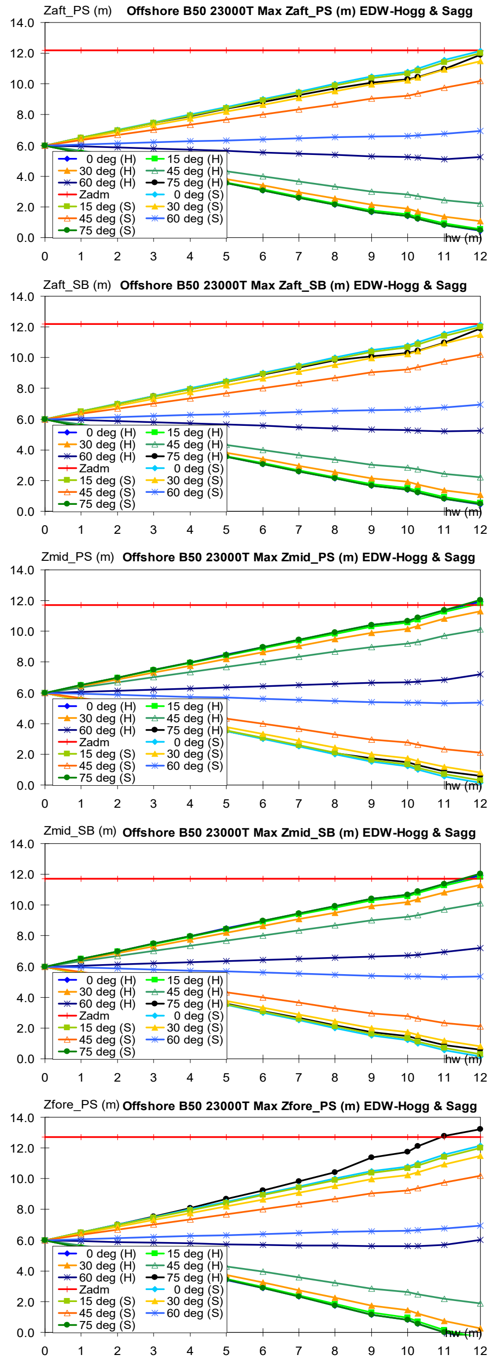


Fig.7 Maximum sectional efforts, Barge B50.

- the freeboard at aft-mid-fore sections, port and starboard sides criteria assessment, using the 1D beam model for Barge B50 (Fig.8).



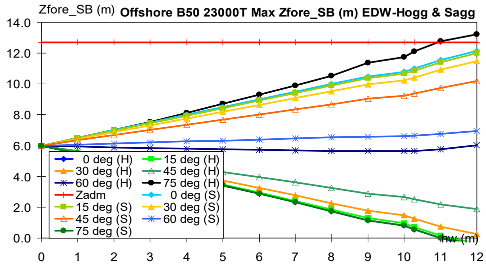


Fig.8 Freeboard assessment, Barge B50.

4. CONCLUSIONS

The limits by global strength criteria for the initial design version Barge 40, in terms of h_w, are presented in Fig.9 and Table 7.

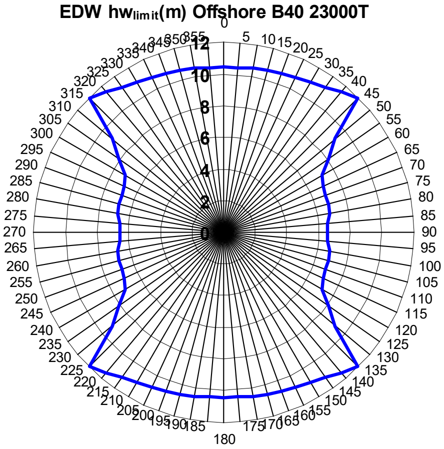


Fig.9 Limits h_w[m], global strength, Barge B40

Table 7. Limits h_w[m], initial design, Barge 40.

μ	*VBM*	*VSF*	*HBM*	*HSF*	*MT*	*FB*
Hogging beam sea (90) waves: **R4(54.7%)**						
0.	12.00	12.00	12.00	12.00	12.00	**10.46**
15.	12.00	12.00	12.00	12.00	12.00	**10.55**
30.	12.00	12.00	12.00	12.00	12.00	**10.91**
45.	12.00	12.00	12.00	12.00	12.00	12.00
60.	12.00	12.00	12.00	12.00	**7.25**	12.00
75.	12.00	12.00	12.00	12.00	**6.84**	**11.35**
85.	12.00	12.00	12.00	12.00	**6.56**	12.00
Sagging beam sea (90) waves: **R4(56.5%)**						
0.	**10.71**	**11.29**	12.00	12.00	12.00	**10.92**
15.	**10.99**	**11.59**	12.00	12.00	12.00	**11.02**
30.	12.00	12.00	12.00	12.00	12.00	**11.54**
45.	12.00	12.00	12.00	12.00	12.00	12.00
60.	12.00	12.00	12.00	12.00	**7.17**	12.00
75.	12.00	12.00	12.00	12.00	**6.80**	12.00
85.	12.00	12.00	12.00	12.00	**6.78**	12.00

The limits by global strength criteria for the second design version Barge 50, in terms of h_w, are presented in Fig.10 and Table 8.

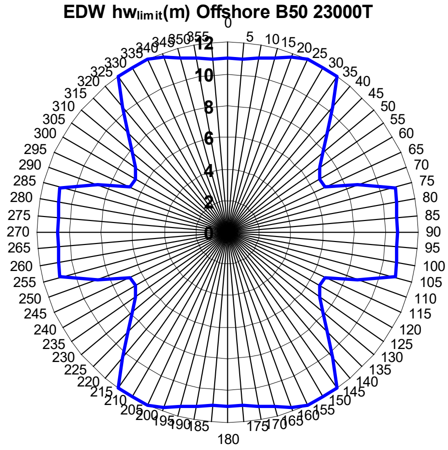


Fig.10 Limits h_w[m], global strength, Barge B50.

Table 8. Limits h_w[m], second design, Barge 50.

μ	*VBM*	*VSF*	*HBM*	*HSF*	*MT*	*FB*
Hogging oblique (60) waves: **R4(55.8%)**						
0.	12.00	12.00	12.00	12.00	12.00	**11.56**
15.	12.00	12.00	12.00	12.00	12.00	**11.81**
30.	12.00	12.00	12.00	12.00	12.00	12.00
45.	12.00	12.00	12.00	12.00	**9.05**	12.00
60.	12.00	12.00	12.00	12.00	**6.70**	12.00
75.	12.00	12.00	12.00	12.00	12.00	**10.91**
85.	**11.72**	**10.97**	12.00	12.00	12.00	**10.73**
Sagging oblique (60) waves: **R4(55.6%)**						
0.	**10.94**	**11.45**	12.00	12.00	12.00	12.00
15.	**11.37**	**11.86**	12.00	12.00	12.00	12.00
30.	12.00	12.00	12.00	12.00	12.00	12.00
45.	12.00	12.00	12.00	12.00	**8.90**	12.00
60.	12.00	12.00	12.00	12.00	**6.67**	12.00
75.	12.00	12.00	12.00	12.00	12.00	12.00
85.	**11.44**	12.00	12.00	12.00	12.00	12.00

Based on the comparative study by 1D global strength and free-board criteria of the two off-shore barge design versions B40 and B50, the following conclusions are obtained:

1. Although both barges have an extended prismatic shape over the length (Fig.1), the specific nonlinear fore-shape leads to visible changes for the sinkage, trim and heeling EDW waves and barges position parameters, over the whole range of the heading angles and wave height (Tables 3, 5).

2. For the bending, shearing and torsion 1D sectional efforts some nonlinear influence of the wave parameters is noticed (Tables 4, 6, Figs. 3, 6).
3. Comparing the admissible strength values (Table 2) for each sectional effort component, it results that for both barges B40, B50 the restrictions occur by *VBM-sagg*, VSF-sagg, *MT-hogg & sagg* criteria (Figs. 4, 7).
4. The freeboard criterion leads to some restrictions for both barges B40, B50 (Figs.5,8).
5. For the initial design of the off-shore barge B40, the major restrictions in operation are recorded at beam sea condition (μ=85-95 deg.), h_{wlimit} = 6.56 m, leading to a navigation restriction class R4 (54.7%) (DNV [4]) (Fig.9, Table 7).
6. For the second design of the off-shore barge B50, the major restrictions in operation are recorded at oblique sea condition (μ= 60; 120 deg.), h_{wlimit} = 6.67 m, leading to a navigation restriction class R4 (55.6%) (DNV [4]) (Fig.10, Table 8).
7. Both design versions have similar navigation class restrictions R4, according to the 1D global strength and free-board criteria. Barge B50 has the main advantage of a wider platform for oversized cargo, but involves extra construction costs (Table 1).
8. Further studies by other criteria and more complex numerical models shall continue this study of the two design versions of the 23000 t off-shore barge.

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