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ON THE GLOBAL STRENGTH ANALYSIS OF PRELIMINARY DESIGN FOR SEVERAL FLOATING DOCK TYPES

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Elisabeta BURLACU, Leonard DOMNISORU

”Dunărea de Jos” University of Galati, Romania

email: leonard.domnisoru@ugal.ro

ABSTRACT

The design concepts of floating docks used for shipyards launching activities have to be assessed from the preliminary design phases by global strength criteria. At initial design, few technical data of floating docks are available, so that the global strength analysis can be developed only on simplified numerical models by the hull equivalent beam method. As loading conditions several docking cases and equivalent design waves, head and oblique conditions, are considered, according to the floating dock design rules. The computations are done with own codes, involving non-linear iterative procedures, which require as input data the 3D-CAD floating docks offset lines and on-board mass distributions. For studying floating dock models, the authors have considered three constructive versions: small dock with continuous and non-continuous side ballast tanks, large dock resulting from a conversion of an off-shore barge. The global strength criteria are the admissible sectional efforts by design rules of statistical values and the ultimate strength vertical bending moment by Smith method. The free board operation criterion is also considered for safety evaluation. The preliminary operation limits of the analyzed floating docks are obtained, in terms of equivalent design wave height, pointing out the main differences between the three constructive versions included in this study.

Keywords: preliminary design, floating docks, global strength, design wave, equivalent beam model

1. INTRODUCTION

At preliminary design phase of a floating dock structure [9], [10], one of the initial evaluations is the global strength by simplified hull equivalent beam method [8], under several operation cases, according to the docks' design rules [4], [5].

This study includes comparative analyses between three floating docks constructive versions, having either different ballast tanks layout on the main deck or lifting capacity [2], [3]. The numerical analyses are developed with own and rules codes (Fig. 1), suitable for the initial design phase [3], [5], [6]. For the floating docks, several operation scenarios are considered, light case, transit state docking operation, maximum lifting capacity loading, according to the design rules [4], [5] and shipyards' docking processes [2].

For each floating dock version, besides the still water condition, also equivalent design wave's loads [8], [9], head or oblique, are considered. Although the equivalent beam model uses a reduced set of input data, typical for preliminary design, the strength of the floating docks can be assessed by design global bending and torsion moments, shear forces and ultimate vertical bending moment criteria [4], [5], [8], [9]. Before any strength assessment, the free-board criterion is also assessed [1].

This study delivers as results the preliminary evaluation of the floating docks operational capabilities in terms of design wave's height limits and makes possible to compare three floating docks constructive versions, which are used in the shipyards docking operations [7].

2. FUNDAMENTS ON GLOBAL STRENGHT ANALYSIS BY EQUIVALENT BEAM MODELS

For the global strength analysis by equivalent beam models [8] under equivalent design waves EDW [9], the authors have developed two codes: D_ACAVD [3] in the case of head and follow design waves, P_QSWD [6] in the case of oblique design waves, with the linked logical flowchart presented in Fig. 1.

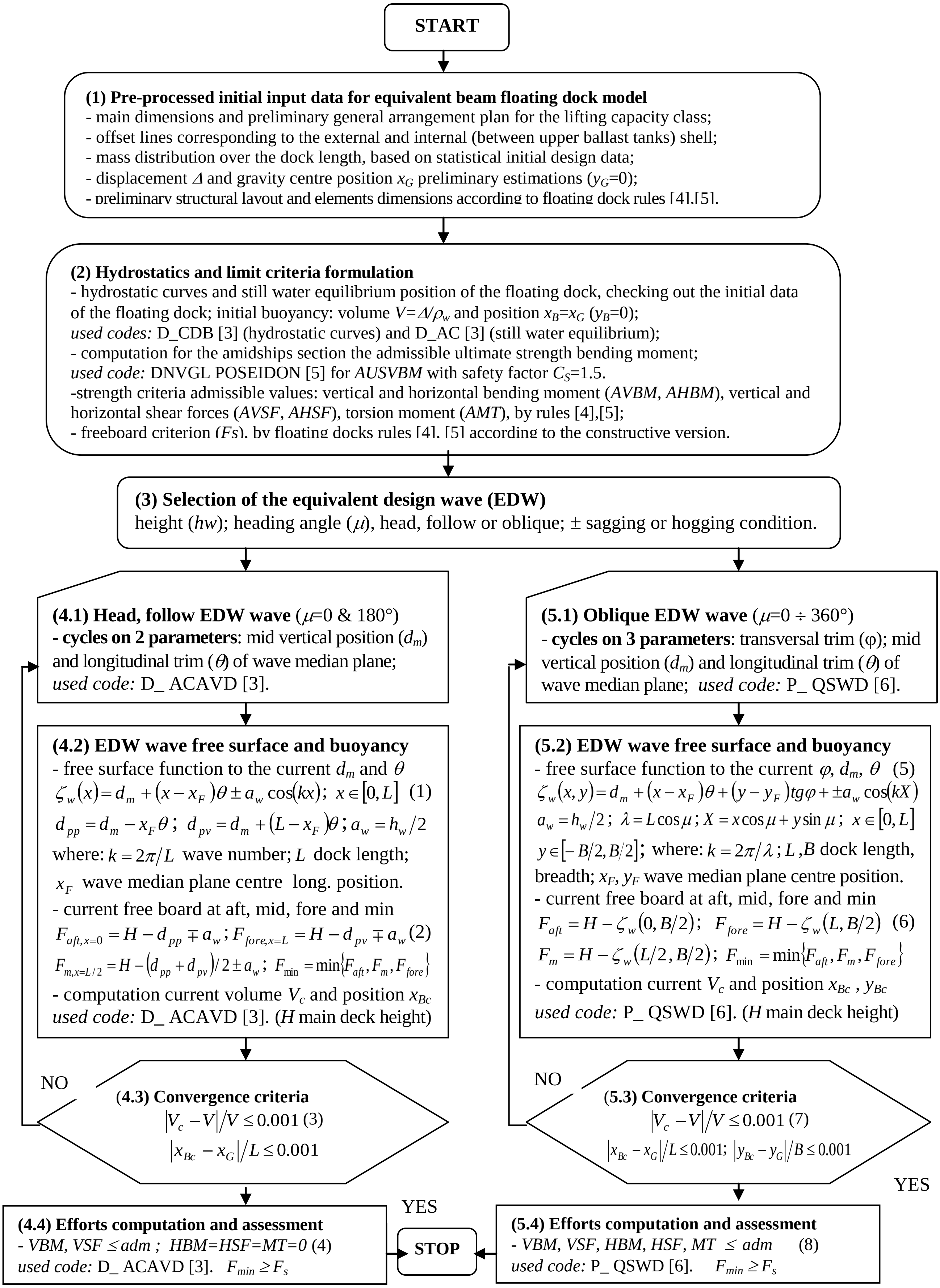

Fig. 1. Logical flowchart of global strength assessment by equivalent beam floating dock models

Module 1 includes the floating docks initial data pre-processing and the equivalent beam model development.

Module 2 involves own codes D_CDB, D_AC [3] for floating docks hydrostatics computation and equilibrium in still water condition (h_w=0). The ultimate strength vertical bending moment USVBM (global buckling) is computed by DNVGL POSEIDON [5] code, for the preliminary structural scantlings of the floating docks. Also in this module the admissible values for sectional efforts and freeboard criterion are selected by floating docks design rules [4], [5].

Module 3 ma kes the selection of the equivalent design wave EDW parameters, switching for one of the numerical codes.

Modules 4.1-4, equations (1)-(4), present in brief the main steps for the two parameters non-linear iterative process for balance between the floating dock hull and head (follow) equivalent design wave by D_ACAVD [3] code.

Modules 5.1-4, equations (5)-(8), present in brief the main steps for the three parameters non-linear iterative process for balance between the floating dock hull and oblique equivalent design wave by P_QSWD [6].

More details for the theoretical bases of algorithms from Fig.1 are presented in the selected references [3], [6].

3. THE FLOATING DOCKS STUDY CASES CHARACTERISTICS

As study cases we have considered three floating docks constructive cases, in order to analyze the main differences that occur from the point of strength criteria at initial design phase.

The first floating dock NWT-Dock60 is small size, length of 60 m, maximum lifting capacity 828 t, with non-continuous side water ballast tanks [3]. Table 1 presents the main data of the NWT-Dock60 equivalent beam dock model. Figures 2a and b present the NWT-Dock60 model under equivalent design waves with h_w=1.278 m, sagging and hogging, quarter-sea μ=45° heading angle. In order to increase the global ultimate strength (US) capacity, very limited for the initial structure [3], we have reconsidered the frames distance $a_{Fr}=a_0$=600mm instead of $a_{Fr}=2a_0$=1200 mm. Figure 3b presents the ultimate strength vertical bending moment USVBM by Smith method [5] for NWT-Dock60 with amidships initial structure from Fig. 3a. At aft and fore peak, where the side ballast tanks are placed above the main deck, the transversal structure becomes similar to the second floating dock (Fig. 5a). For NWT-Dock60 are considered the following loading cases: light without docking mass, ship 1 with uniform docking mass, ship 2 with sagging docking mass and ship 3 with hogging mass distribution, according to dock design rules [5]. See mass distributions in Figures 6a and b.

The second floating dock CWT-Dock60 is small size, length of 60 m, maximum lifting capacity 828 t, with continuous side water ballast tanks caisson type [3], [5]. The main data of the CWT-Dock60 equivalent beam dock model are in Table 1. Figs.4.a.b presents the CWT-Dock60 model under equivalent design wave with h_w=1.930 m, sagging and hogging, quarter-sea μ=45° heading angle. Similar to the first dock NWT-Dock60, so that we have a same structural reference, the frames distance is reconsidered at $a_{Fr}=a_0$=600 mm instead of $a_{Fr}=2a_0$=1200 mm [3]. Fig.5.b presents the ultimate strength vertical bending moment USVBM by Smith method [5] for CWT-Dock60 with amidships initial structure from Fig.5.a. For CWT-Dock60 are considered same four mass distribution cases, with diagrams not included in this paper.

The third floating dock DOCKV is large size, length of 209.2 m, maximum lifting capacity 27000 t, with non-continuous side water ballast tanks [2]. A selection of the main data of the DOCKV equivalent beam dock model is presented in Table 1. Figs. 7.a.b presents the DOCKV model under equivalent design wave with h_w=4.492 m, sagging and hogging, head wave μ=0 condition. The frames distance is $a_{Fr}=4a_0$=3000mm [2]. Figure 8b presents the ultimate strength vertical bending moment USVBM by Smith method [5] for DOCKV with amidships initial structure from Fig. 8a. The following DOCKV loading cases are considered: light case without docking mass and with ballast, D19747 t with shipyard docking test mass [2], D27000 t (unif.) with uniform docking mass, D27000 t (hogg.) with hogging mass distribution and D27000 t (sagg.) with sagging docking mass, according to dock design rules [4], [5]. See mass distributions in Figures 9a, b, c. In order to have the quay transfer required main deck level, the on-board ballast system ensures a draught constant level of T_m=6.2 m for all docking cases.

Table 2 presents the global strength admissible values, based on dock design rules [4], [5], for *VBM* [kNm] vertical bending moment, *VSF* [kN] vertical shear force, *HBM* [kNm] horizontal bending moment, *HSF* [kN] horizontal shear force, *MT* [kNm] torsion moment, including *USVBM* [kNm] ultimate strength vertical moment and freeboard F_s [m] criteria.

The floating docks are analyzed up to the maximum EDW equivalent design wave height [5], corresponding to the maximum river class IN(2.0) and costal class RE(50%) for the floating docks operation water areas conditions.

Table 1. The floating docks study cases main characteristics [2], [3]

Floating dock version			NWT-Dock60 (Figs.2.a,b)	CWT-Dock60 (Figs.4.a,b)	DOCKV (Figs.7.a,b)
Side water ballast tanks type			Non-continuous	Continuous	Non-continuous
$M_{lift}[t]$	maximum lifting mass		828	828	27000
L[m]	length		60	60	209.2
B[m]	breadth		20	20	55.13
B_{max}[m]	maximum breadth		20	20	61.09
H [m]	pontoon deck height		2	2	10.10
a_0[mm]	regular distance		600	600	750
a_{Fr}[mm]	frames distance		600	600	3000
NS	number of stations beam model		300	300	280
z_N[m]	neutral axis vertical position		1.000	2.728	5.139
z_R[m]	torsion centre vertical position		1.000	-1.168	5.139
Material type			steel grade A	steel grade A	steel grade AH36
h_{wmax}[m]	max. wave height RE(50%)		2.568	2.568	4.492
μ [°]	EDW heading angle		0÷360 oblique	0÷360 oblique	0 head (180 follow)
Δ[t]	displacement	Light	960	1152	66324
		Docking	1788	1980	66324
x_G[m]	gravity centre long. position		30	30	100.148
y_G[m]	gravity centre vert. position		0	0	0
T_m[m]	medium draught in still water	Light	0.800	0.960	6.200
		Docking	1.490	1.650	6.200
θ [rad]	longitudinal trim in still water		0	0	0
φ [rad]	transversal trim in still water		0	0	0

Table 2. The admissible values for global strength equivalent beam model formulation for floating docks versions [4],[5]

Floating dock version	USVBM [kNm] ultimate	AUSVBM [kNm] (cs=1.5)	VBM-adm [kNm] rules	AVBM [kNm] combined	AVSF [kN] rules	AHBM [kNm] rules	AHSF [kN] rules	AMT [kNm] rules	Fs [m] rules
NWT-Dock60	3.41E+04	2.27E+04	5.56E+04	2.27E+04	3.14E+03	4.26E+03	2.11E+02	2.44E+04	0.300
CWT-Dock60	9.48E+04	6.32E+04	5.56E+04	5.56E+04	3.14E+03	5.11E+03	2.54E+02	2.44E+04	0.075
DOCKV	7.97E+06	5.32E+06	3.44E+06	3.44E+06	5.70E+04	8.62E+05	1.23E+04	1.08E+06	0.300

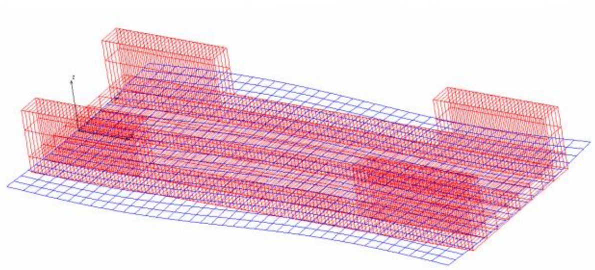

Fig. 2a. NWT-Dock60, light case, EDW wave hogging, h_w=1.278 m, quarter-sea μ=45°, and offset lines [3]

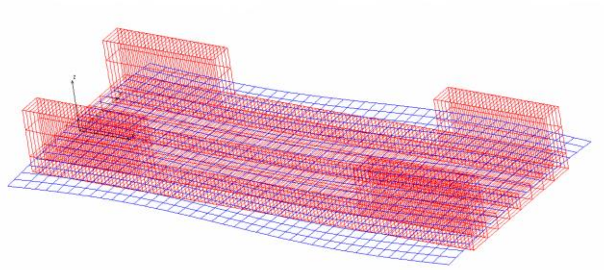

Fig. 2b. NWT-Dock60, light case, EDW wave sagging, h_w=1.278 m, quarter-sea μ=45°, and offset lines [3]

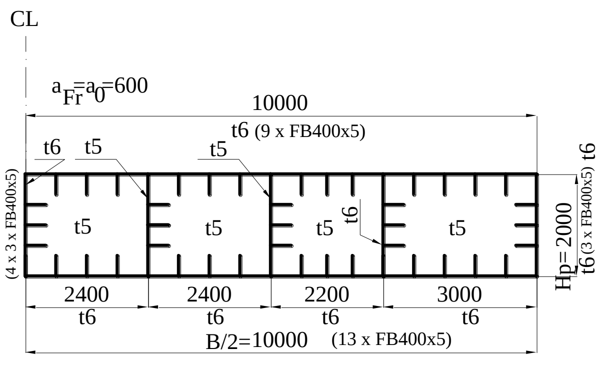

Fig. 3a. NWT-Dock60 amidships transversal floating dock preliminary structure [3]

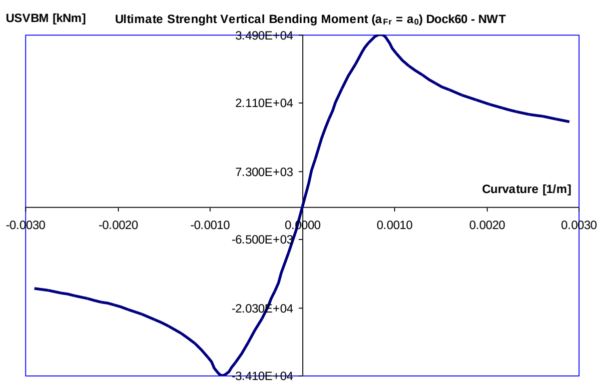

Fig. 3b. NWT-Dock60 ultimate strength vertical bending moment USVBM [kNm], a_{Fr}=a_0=600 mm

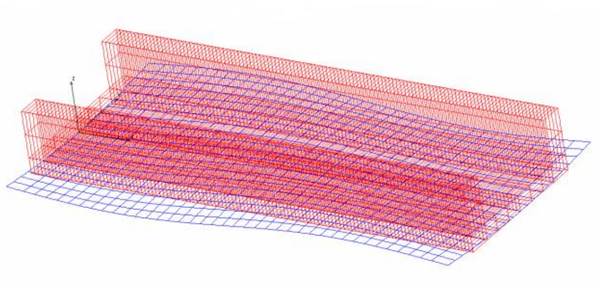

Fig. 4a. CWT-Dock60, light case, EDW wave hogging, h_w=1.930 m, quarter-sea μ=45°, and offset lines [3]

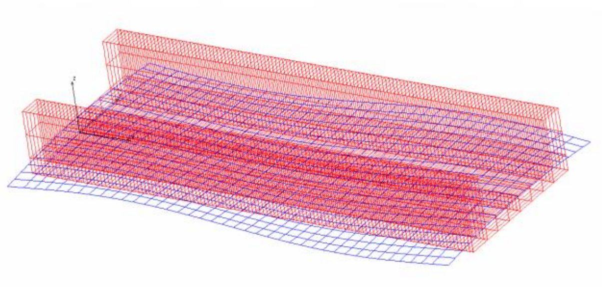

Fig. 4b. CWT-Dock60, light case, EDW wave sagging, h_w=1.930 m, quarter-sea μ=45°, and offset lines [3]

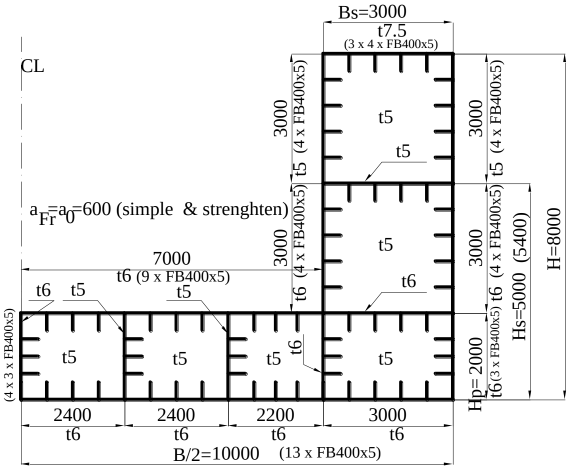

Fig. 5a CWT-Dock60 amidships transversal floating dock preliminary structure [3]

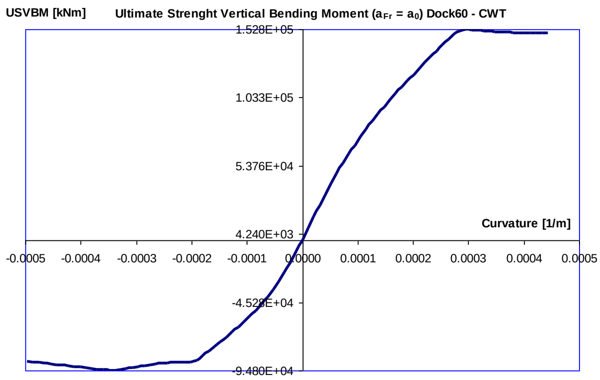

Fig. 5b CWT-Dock60 ultimate strength vertical bending moment USVBM [kNm], a_{Fr}=a_0=600 mm

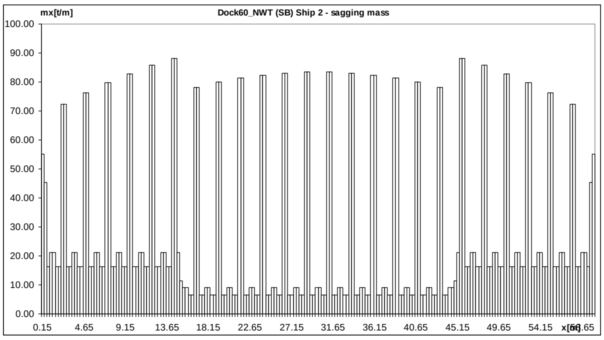

Fig. 6a. NWT-Dock60, ship 2 case, with sagging docking mass distribution [3]

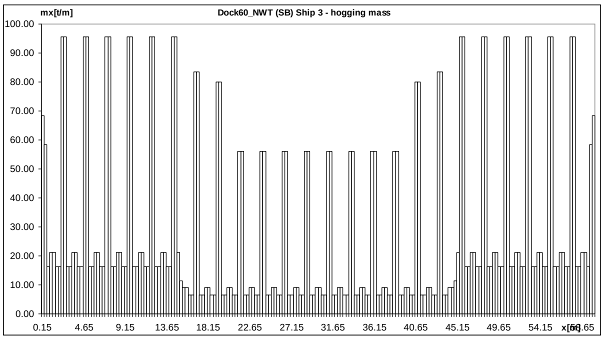

Fig. 6b. NWT-Dock60, ship 3 case, with hogging docking mass distribution [3]

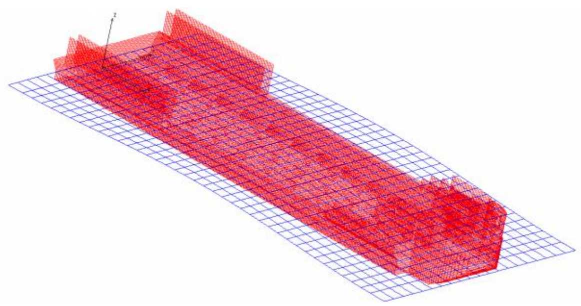

Fig.7a. DOCKV, light case, EDW wave hogging, h_w=4.492 m, head μ=0 condition, and offset lines [2]

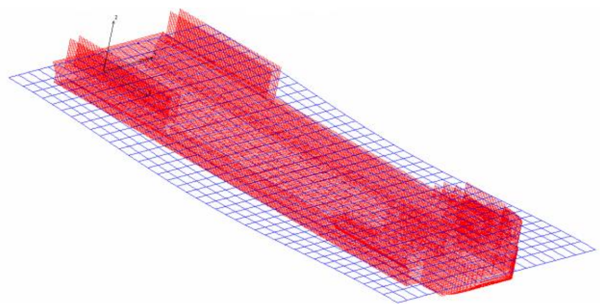

Fig. 7b. DOCKV, light case, EDW wave sagging, h_w=4.492 m, head μ=0 condition, and offset lines [2]

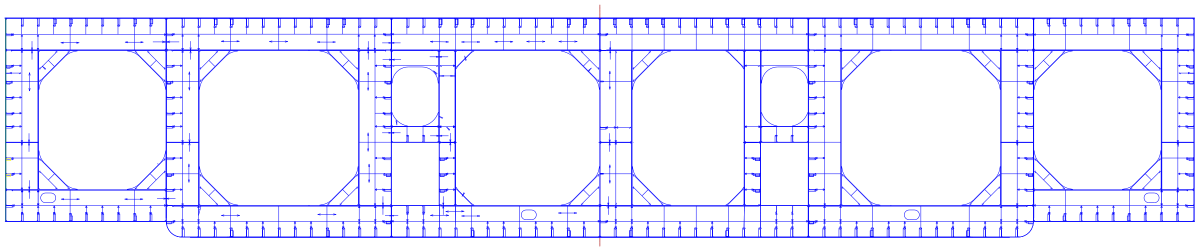

Fig. 8a DOCKV amidships transversal floating dock structure [2]

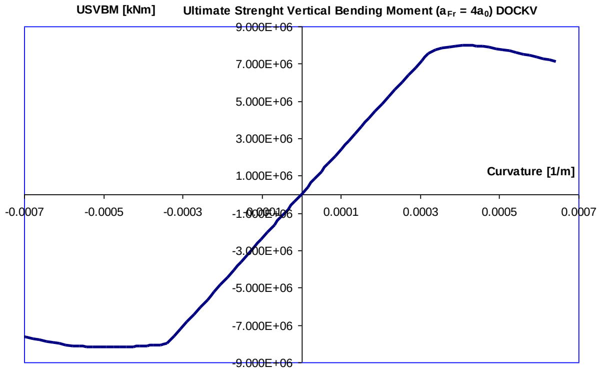

Fig. 8b. DOCKV ultimate strength vertical bending moment USVBM [kNm], a_{Fr}=4a_0=3000 mm

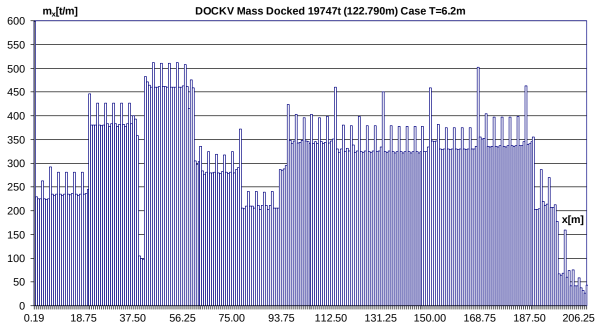

Fig. 9a. DOCKV D19747t (& ball), mass disitribution, shipyard docking case, T_m=6.2 m [2]

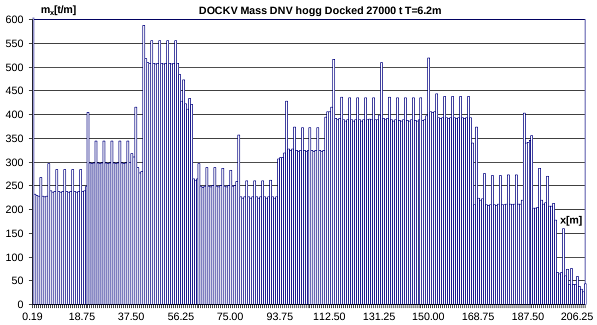

Fig. 9b. DOCKV D27000t (&ball) hogg-mass, with hogging docking mass distribution, T_m=6.2 m [2]

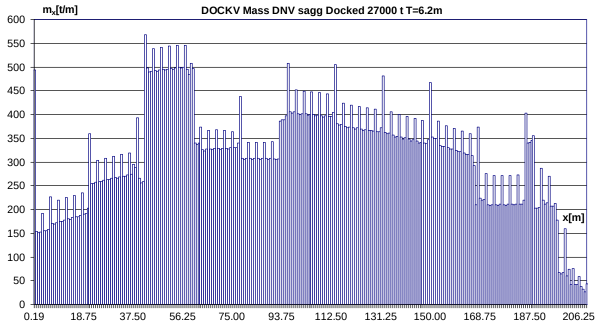

Fig. 9c. DOCKV D27000t (&ball) sagg-mass, with sagging docking mass distribution,T_m=6.2 m [2]

4. FLOATING DOCKS NWT-DOCK60 AND CWT-DOCK60 GLOBAL STRENGHT ANALYSIS IN OBLIQUE WAVES, BY NUMERICAL EQUIVALENT DOCK BEAM MODELS

In the cases of oblique equivalent design waves, taking into account that the NWT-Dock60 and CWT-Dock60 floating docks have double symmetry planes (Figs. 2a, b and Figs. 4a, b), the heading angle can be considered only for μ=0÷90°, with δμ=15° step. The global strength analysis by equivalent beam model, under oblique waves, of the NWT-Dock60 and CWT-Dock60 versions, using P_QSWD [6] program, with modules 5.1-5.4 from Fig. 1, lead to the global strength and free board criteria check for all four loading cases from Tables 3a-d (CWT) and Tables 4a-d (NWT).

Table 3a. Global strength and free board criteria, NWT Dock60 light displacement case

NWT light	μ[°]	0	max/ adm	15	max/ adm	30	max/ adm	45	max/ adm	60	max/ adm	75	max/ adm	90	max/ adm
h_{wlim}[m]	wave	0.640		0.666		0.778		1.278		1.800		1.800		1.800	
Free board	hogg	0.880	>1	0.867	>1	0.811	>1	0.561	>1	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**
	sagg	0.880	>1	0.867	>1	0.811	>1	0.561	>1	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**
VBM [kNm]	hogg	2.27E+4	**1.00**	2.27E+4	**1.00**	2.27E+4	**1.00**	2.27E+4	**1.00**	1.01E+4	0.45	6.43E+3	0.28	0	0
	sagg	2.99E+2	0.01	2.99E+2	0.01	2.96E+2	0.01	3.03E+2	0.01	1.58E+4	0.69	2.16E+4	0.95	0	0
VSF [kN]	hogg	1.33E+3	0.42	1.33E+3	0.42	1.33E+3	0.42	1.33E+3	0.42	5.61E+2	0.18	4.35E+2	0.14	0	0
	sagg	1.29E+2	0.04	1.29E+2	0.04	1.29E+2	0.04	1.30E+2	0.04	8.91E+2	0.28	1.56E+3	0.49	0	0
HBM [kNm]	hogg	0	0	6.67E+1	0.02	1.60E+2	0.04	4.00E+2	0.09	5.42E+2	0.13	2.77E+2	0.07	0	0
	sagg	0	0	4.67E+1	0.01	1.12E+2	0.03	2.80E+2	0.07	6.48E+2	0.15	4.60E+2	0.11	0	0
HSF [kN]	hogg	0	0	8.98E+0	0.04	2.15E+1	0.10	5.39E+1	0.26	6.06E+1	0.29	3.05E+1	0.14	0	0
	sagg	0	0	4.84E+0	0.02	1.16E+1	0.05	2.91E+1	0.14	8.19E+1	0.39	6.07E+1	0.29	0	0
MT [kNm]	hogg	0	0	1.72E+3	0.07	4.12E+3	0.17	1.03E+4	0.42	1.61E+4	0.66	1.10E+4	0.45	1.59E+4	0.70
	sagg	0	0	1.72E+3	0.07	4.13E+3	0.17	1.03E+4	0.42	1.61E+4	0.66	1.10E+4	0.45	4.98E+3	0.22

Table 3b. Global strength and free board criteria, NWT Dock60 ship 1 displacement case

NWT ship 1	μ[°]	0	max/ adm	15	max/ adm	30	max/ adm	45	max/ adm	60	max/ adm	75	max/ adm	90	max/ adm
h_{wlim}[m]	wave	0.420		0.420		0.420		0.420		0.420		0.420		0.420	
Free	hogg	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**
board	sagg	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**
VBM	hogg	2.12E+4	0.93	2.09E+4	0.92	1.99E+4	0.87	1.75E+4	0.77	1.19E+4	0.52	8.29E+3	0.36	0	0
[kNm]	sagg	6.18E+3	0.27	6.47E+3	0.28	7.51E+3	0.33	9.93E+3	0.44	1.55E+4	0.68	1.91E+4	0.84	0	0
VSF	hogg	1.31E+3	0.42	1.30E+3	0.41	1.25E+3	0.40	1.12E+3	0.36	8.27E+2	0.26	6.39E+2	0.20	0	0
[kN]	sagg	5.28E+2	0.17	5.44E+2	0.17	5.98E+2	0.19	7.25E+2	0.22	1.02E+3	0.32	1.20E+3	0.38	0	0
HBM	hogg	0	0	7.00E+1	0.02	1.43E+2	0.03	2.13E+2	0.05	2.28E+2	0.05	1.58E+2	0.04	0	0
[kNm]	sagg	0	0	6.20E+1	0.01	1.28E+2	0.03	2.00E+2	0.05	2.35E+2	0.06	1.73E+2	0.04	0	0
HSF	hogg	0	0	8.94E+0	0.04	1.81E+1	0.09	2.67E+1	0.13	2.77E+1	0.13	1.88E+1	0.09	0	0
[kN]	sagg	0	0	7.29E+0	0.03	1.52E+1	0.07	2.40E+1	0.11	2.92E+1	0.14	2.19E+1	0.10	0	0
MT	hogg	0	0	1.08E+3	0.04	2.23E+3	0.09	3.39E+3	0.14	3.80E+3	0.16	2.72E+3	0.11	1.85E+3	0.08
[kNm]	sagg	0	0	1.08E+3	0.04	2.23E+3	0.09	3.39E+3	0.14	3.80E+3	0.16	2.72E+3	0.11	3.16E+3	0.14

Table 3c. Global strength and free board criteria, NWT Dock60 ship 2 displacement case

NWT ship 2	μ[°]	0	max/ adm	15	max/ adm	30	max/ adm	45	max/ adm	60	max/ adm	75	max/ adm	90	max/ adm
h_{wlim}[m]	wave	0.420		0.420		0.420		0.420		0.420		0.420		0.420	
Free	hogg	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300
board	sagg	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300
VBM	hogg	1.38E+4	0.61	1.35E+4	0.59	1.25E+4	0.55	1.01E+4	0.44	4.50E+3	0.20	9.36E+2	0.04	0	0
[kNm]	sagg	1.32E+3	0.06	1.02E+3	0.05	3.04E+2	0.01	2.53E+3	0.11	8.09E+3	0.36	1.17E+4	0.51	0	0
VSF	hogg	9.90E+2	0.31	9.74E+2	0.31	9.20E+2	0.29	7.93E+2	0.25	5.02E+2	0.16	3.14E+2	0.10	0	0
[kN]	sagg	2.65E+2	0.08	2.52E+2	0.08	2.73E+2	0.09	4.00E+2	0.13	6.91E+2	0.22	8.79E+2	0.28	0	0
HBM	hogg	0	0	7.00E+1	0.02	1.43E+2	0.03	2.13E+2	0.05	2.28E+2	0.05	1.58E+2	0.04	0	0
[kNm]	sagg	0	0	6.20E+1	0.01	1.28E+2	0.03	2.00E+2	0.05	2.35E+2	0.06	1.73E+2	0.04	0	0
HSF	hogg	0	0	8.94E+0	0.04	1.81E+1	0.09	2.67E+1	0.13	2.77E+1	0.13	1.88E+1	0.09	0	0
[kN]	sagg	0	0	7.29E+0	0.03	1.52E+1	0.07	2.40E+1	0.11	2.92E+1	0.14	2.19E+1	0.10	0	0
MT	hogg	0	0	1.08E+3	0.04	2.23E+3	0.09	3.39E+3	0.14	3.80E+3	0.16	2.72E+3	0.11	1.85E+3	0.08
[kNm]	sagg	0	0	1.08E+3	0.04	2.23E+3	0.09	3.39E+3	0.14	3.80E+3	0.16	2.72E+3	0.11	3.16E+3	0.14

Table 3d. Global strength and free board criteria, NWT Dock60 ship 3 displacement case

NWT ship3	μ[°]	0	max/ adm	15	max/ adm	30	max/ adm	45	max/ adm	60	max/ adm	75	max/ adm	90	max/ adm
h_{wlim}[m]	wave	0.261		0.272		0.318		0.420		0.420		0.420		0.420	
Free	hogg	0.379	1.26	0.374	1.24	0.351	1.17	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**
board	sagg	0.379	1.26	0.374	1.24	0.351	1.17	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**	0.300	**1.00**
VBM	hogg	2.27E+4	**1.00**	2.27E+4	**1.00**	2.27E+4	**1.00**	2.18E+4	0.96	1.63E+4	0.72	1.27E+4	0.56	0	0
[kNm]	sagg	1.34E+4	0.59	1.34E+4	0.59	1.34E+4	0.59	1.43E+4	0.63	1.96E+4	0.86	2.18E+4	0.96	0	0
VSF	hogg	1.37E+3	0.44	1.44E+3	0.46	1.44E+3	0.46	1.39E+3	0.44	1.10E+3	0.35	9.18E+2	0.29	0	0
[kN]	sagg	9.56E+2	0.30	9.55E+2	0.30	9.55E+2	0.30	1.00E+3	0.32	1.29E+3	0.41	1.48E+3	0.47	0	0
HBM	hogg	0	0	4.44E+1	0.01	1.07E+2	0.03	2.13E+2	0.05	2.28E+2	0.05	1.58E+2	0.04	0	0
[kNm]	sagg	0	0	4.10E+1	0.01	9.85E+1	0.02	2.00E+2	0.05	2.35E+2	0.06	1.73E+2	0.04	0	0
HSF	hogg	0	0	5.60E+0	0.03	1.34E+1	0.06	2.67E+1	0.13	2.77E+1	0.13	1.88E+1	0.09	0	0
[kN]	sagg	0	0	4.91E+0	0.02	1.18E+1	0.06	2.40E+1	0.11	2.92E+1	0.14	2.19E+1	0.10	0	0
MT	hogg	0	0	7.02E+2	0.03	1.69E+3	0.07	3.39E+3	0.14	3.80E+3	0.16	2.72E+3	0.11	1.85E+3	0.08
[kNm]	sagg	0	0	7.02E+2	0.03	1.69E+3	0.07	3.39E+3	0.14	3.80E+3	0.16	2.72E+3	0.11	3.16E+3	0.14

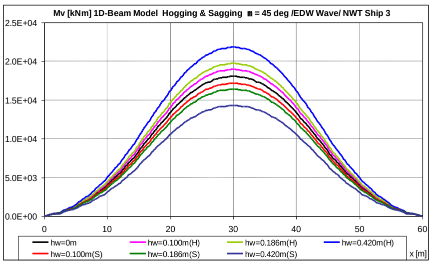

Fig. 10a. VBM, ship3, μ=45°, NWT

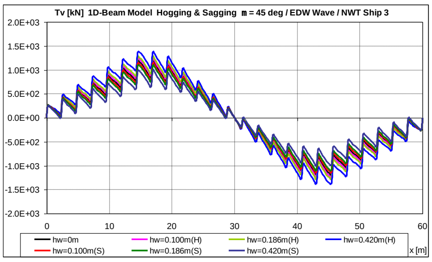

Fig. 10b. VSF, ship3, μ=45°, NWT

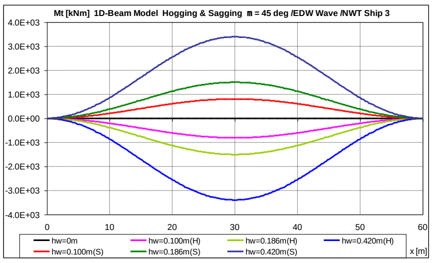

Fig. 10c. MT, ship3, μ=45°, NWT

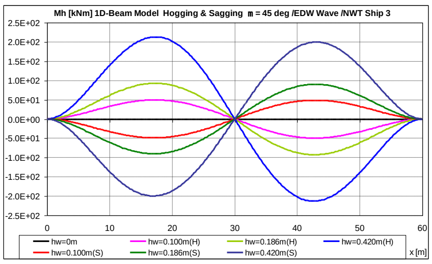

Fig. 10d. HBM, ship3, μ=45°, NWT

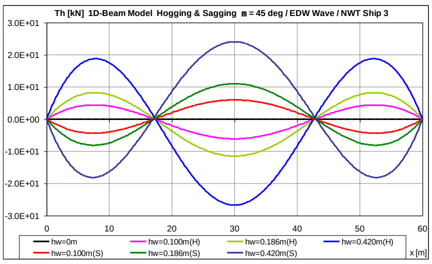

Fig. 10e. HSF, ship3, μ=45°, NWT

Table 4a. Global strength and free board criteria, CWT Dock60 light displacement case

CWT light	μ[°]	0	max/ adm	15	max/ adm	30	max/ adm	45	max/ adm	60	max/ adm	75	max/ adm	90	max/ adm
h_{wlim}[m]	wave	1.930		1.930		1.930		1.930		1.930		1.930		1.930	
Free	hogg	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**
board	sagg	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**
VBM	hogg	4.40E+4	0.79	4.27E+4	0.77	3.82E+4	0.69	2.81E+4	0.51	1.97E+3	0.04	1.53E+4	0.28	0	0
[kNm]	sagg	2.50E+4	0.45	2.38E+4	0.43	1.92E+4	0.35	7.80E+3	0.14	1.45E+4	0.26	3.43E+4	0.62	0	0
VSF	hogg	2.41E+3	0.77	2.34E+3	0.75	2.10E+3	0.67	1.56E+3	0.50	1.97E+2	0.06	7.83E+2	0.25	0	0
[kN]	sagg	1.28E+3	0.41	1.22E+3	0.39	9.79E+2	0.31	4.23E+2	0.13	9.24E+2	0.29	1.90E+3	0.61	0	0
HBM	hogg	0	0	2.87E+2	0.06	5.63E+2	0.11	7.58E+2	0.15	7.58E+2	0.15	3.54E+2	0.07	0	0
[kNm]	sagg	0	0	1.27E+2	0.02	2.77E+2	0.05	4.94E+2	0.10	4.94E+2	0.10	6.87E+2	0.13	0	0
HSF	hogg	0	0	4.15E+1	0.16	8.01E+1	0.32	1.04E+2	0.41	6.94E+1	0.27	3.90E+1	0.15	0	0
[kN]	sagg	0	0	1.52E+1	0.06	3.16E+1	0.12	5.05E+1	0.20	9.87E+1	0.39	9.63E+1	0.38	0	0
MT	hogg	0	0	5.06E+3	0.21	1.04E+4	0.43	1.58E+4	0.65	1.76E+4	0.72	1.26E+4	0.51	2.15E+4	0.39
[kNm]	sagg	0	0	5.00E+3	0.20	1.03E+4	0.42	1.57E+4	0.64	1.77E+4	0.72	1.27E+4	0.52	1.46E+3	0.03

Table 4b. Global strength and free board criteria, CWT Dock60 ship 1 displacement case

CWT ship1	μ[°]	0	max/ adm	15	max/ adm	30	max/ adm	45	max/ adm	60	max/ adm	75	max/ adm	90	max/ adm
h_{wlim}[m]	wave	0.550		0.550		0.550		0.550		0.550		0.550		0.550	
Free	hogg	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	1.00	0.075	**1.00**	0.075	**1.00**
board	sagg	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**
VBM	hogg	2.17E+4	0.39	2.13E+4	0.38	2.00E+4	0.36	1.68E+4	0.30	9.53E+3	0.17	4.81E+3	0.09	0	0
[kNm]	sagg	2.26E+3	0.04	2.56E+3	0.05	3.79E+3	0.07	6.96E+3	0.13	1.42E+4	0.26	1.90E+4	0.34	0	0
VSF	hogg	1.33E+3	0.42	1.31E+3	0.42	1.24E+3	0.39	1.07E+3	0.34	6.92E+2	0.22	4.45E+2	0.14	0	0
[kN]	sagg	3.71E+2	0.12	3.71E+2	0.12	3.92E+2	0.12	5.58E+2	0.18	9.39E+2	0.30	1.19E+3	0.38	0	0
HBM	hogg	0	0	1.03E+2	0.02	2.09E+2	0.04	3.10E+2	0.06	3.29E+2	0.06	2.27E+2	0.04	0	0
[kNm]	sagg	0	0	8.89E+1	0.02	1.84E+2	0.04	2.88E+2	0.06	3.41E+2	0.07	2.53E+2	0.05	0	0
HSF	hogg	0	0	1.32E+1	0.05	2.66E+1	0.11	3.91E+1	0.15	4.00E+1	0.16	2.68E+1	0.11	0	0
[kN]	sagg	0	0	1.04E+1	0.04	2.17E+1	0.09	3.45E+1	0.14	4.25E+1	0.17	3.21E+1	0.13	0	0
MT	hogg	0	0	1.45E+3	0.06	2.97E+3	0.12	4.53E+3	0.19	5.07E+3	0.21	3.62E+3	0.15	7.23E+3	0.13
[kNm]	sagg	0	0	1.44E+3	0.06	2.96E+3	0.12	4.52E+3	0.18	5.07E+3	0.21	3.63E+3	0.15	9.11E+2	0.02

Table 4c. Global strength and free board criteria, CWT Dock60 ship 2 displacement case

CWT ship2	μ[°]	0	max/ adm	15	max/ adm	30	max/ adm	45	max/ adm	60	max/ adm	75	max/ adm	90	max/ adm
h_{wlim}[m]	wave	0.550		0.550		0.550		0.550		0.550		0.550		0.550	
Free	hogg	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	1.00	0.075	**1.00**	0.075	**1.00**
board	sagg	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**
VBM	hogg	1.43E+4	0.26	1.39E+4	0.25	1.26E+4	0.23	9.41E+3	0.17	2.13E+3	0.04	2.68E+3	0.05	0	0
[kNm]	sagg	5.43E+3	0.10	5.05E+3	0.09	3.70E+3	0.07	5.38E+2	0.01	6.85E+3	0.12	1.16E+4	0.21	0	0
VSF	hogg	1.01E+3	0.32	9.85E+2	0.31	9.14E+2	0.29	7.48E+2	0.24	3.67E+2	0.12	3.11E+2	0.10	0	0
[kN]	sagg	4.32E+2	0.14	4.15E+2	0.13	3.56E+2	0.11	2.33E+2	0.07	6.14E+2	0.20	8.60E+2	0.27	0	0
HBM	hogg	0	0	1.03E+2	0.02	2.09E+2	0.04	3.10E+2	0.06	3.29E+2	0.06	2.27E+2	0.04	0	0
[kNm]	sagg	0	0	8.89E+1	0.02	1.84E+2	0.04	2.88E+2	0.06	3.41E+2	0.07	2.53E+2	0.05	0	0
HSF	hogg	0	0	1.32E+1	0.05	2.66E+1	0.11	3.91E+1	0.15	4.00E+1	0.16	2.68E+1	0.11	0	0
[kN]	sagg	0	0	1.04E+1	0.04	2.17E+1	0.09	3.45E+1	0.14	4.25E+1	0.17	3.21E+1	0.13	0	0
MT	hogg	0	0	1.45E+3	0.06	2.97E+3	0.12	4.53E+3	0.19	5.07E+3	0.21	3.62E+3	0.15	7.23E+3	0.13
[kNm]	sagg	0	0	1.44E+3	0.06	2.96E+3	0.12	4.52E+3	0.18	5.07E+3	0.21	3.63E+3	0.15	9.11E+2	0.02

Table 4d. Global strength and free board criteria, CWT Dock60 ship 3 displacement case

CWT ship3	μ[°]	0	max/ adm	15	max/ adm	30	max/ adm	45	max/ adm	60	max/ adm	75	max/ adm	90	max/ adm
h_{wlim}[m]	wave	0.550		0.550		0.550		0.550		0.550		0.550		0.550	
Free	hogg	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	1.00	0.075	**1.00**	0.075	**1.00**
board	sagg	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**	0.075	**1.00**
VBM	hogg	2.61E+4	0.47	2.57E+4	0.46	2.44E+4	0.44	2.12E+4	0.38	1.39E+4	0.25	9.18E+3	0.17	0	0
[kNm]	sagg	6.41E+3	0.12	6.80E+3	0.12	8.16E+3	0.15	1.13E+4	0.20	1.86E+4	0.33	2.33E+4	0.42	0	0
VSF	hogg	1.60E+3	0.51	1.58E+3	0.50	1.51E+3	0.48	1.34E+3	0.43	9.64E+2	0.31	7.20E+2	0.23	0	0
[kN]	sagg	5.78E+2	0.18	5.98E+2	0.19	6.67E+2	0.21	8.30E+2	0.26	1.21E+3	0.39	1.46E+3	0.46	0	0
HBM	hogg	0	0	1.03E+2	0.02	2.09E+2	0.04	3.10E+2	0.06	3.29E+2	0.06	2.27E+2	0.04	0	0
[kNm]	sagg	0	0	8.89E+1	0.02	1.84E+2	0.04	2.88E+2	0.06	3.41E+2	0.07	2.53E+2	0.05	0	0
HSF	hogg	0	0	1.32E+1	0.05	2.66E+1	0.11	3.91E+1	0.15	4.00E+1	0.16	2.68E+1	0.11	0	0
[kN]	sagg	0	0	1.04E+1	0.04	2.17E+1	0.09	3.45E+1	0.14	4.25E+1	0.17	3.21E+1	0.13	0	0
MT	hogg	0	0	1.45E+3	0.06	2.97E+3	0.12	4.53E+3	0.19	5.07E+3	0.21	3.62E+3	0.15	7.23E+3	0.13
[kNm]	sagg	0	0	1.44E+3	0.06	2.96E+3	0.12	4.52E+3	0.18	5.07E+3	0.21	3.63E+3	0.15	9.11E+2	0.02

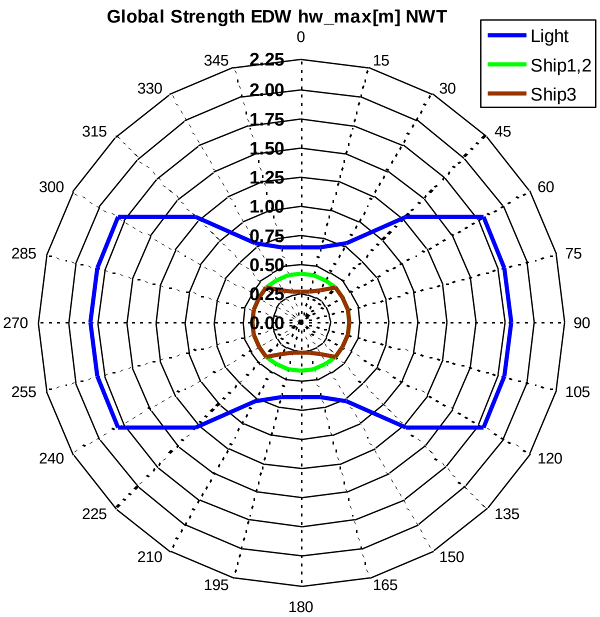

Fig. 11a. NWT-Dock60 polar diagram of EDW wave height limit h_{wlimit}, all four loading cases, beam model

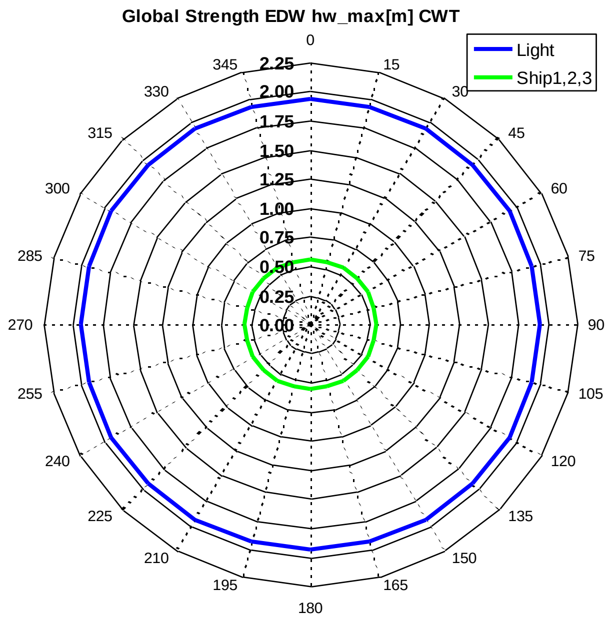

Fig. 11b. CWT-Dock60 polar diagram of EDW wave height limit h_{wlimit}, all four loading cases, beam model

Figures 10a-e present the VBM, VSF, HBM, HSF, MT diagrams at μ=45°, for NWT-Dock60 ship 3 case

Figures 11a and b present the polar diagrams of EDW wave height limit hwlimit for NWT-Dock60 and CWT-Dock60.

5. FLOATING DOCKV GLOBAL STRENGHT ANALYSIS IN HEAD WAVES BY NUMERICAL EQUIVALENT DOCK BEAM MODEL

The global strength analysis by equivalent beam model, under head wave, of the DOCKV version, using P_ACAVD [3] program, with modules 4.1-4.4 from Fig.1, lead to the global strength and free board criteria check in Tables 5.a-g.

Figs.12.a,b present the VBM, VSF diagrams during docking transition for shipyard case, for L_d=0÷122.79 m (still water) over the pontoon deck, and Figs.12.c-f at head wave (μ=0) for DOCK D19747 t case, L_{dmax}=122.79 m.

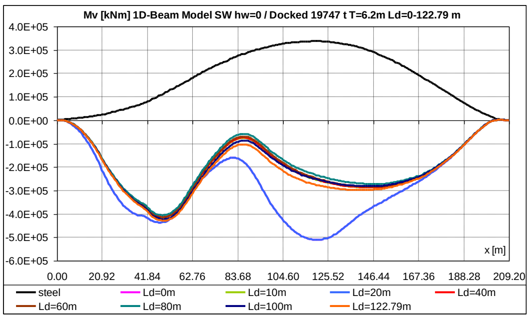

Fig. 12a. VBM, L_d=0÷122.79 m, sw, μ=0

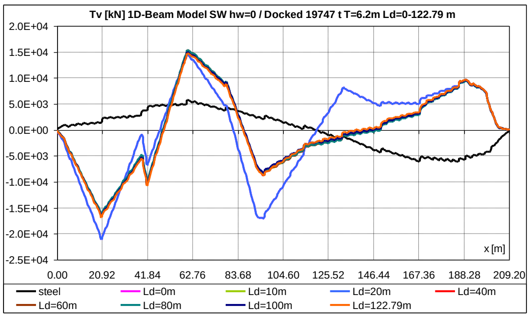

Fig. 12b. VSF, L_d=0÷122.79m, sw, μ=0

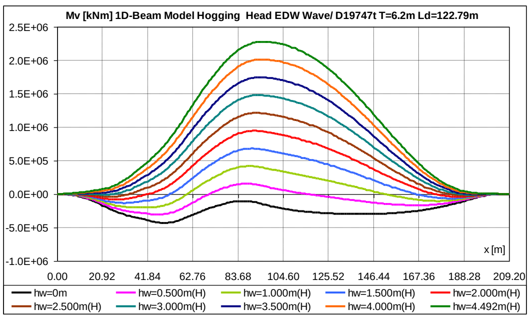

Fig. 12c VBM, D19747t, hogg., μ=0

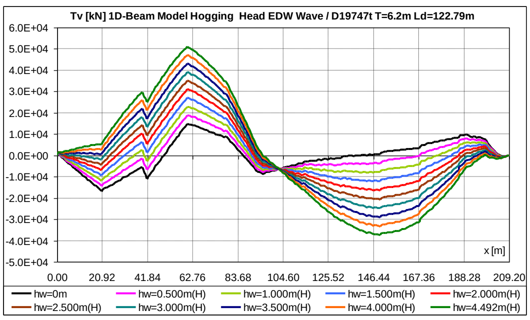

Fig. 12d. VSF, D19747t, hogg., μ=0

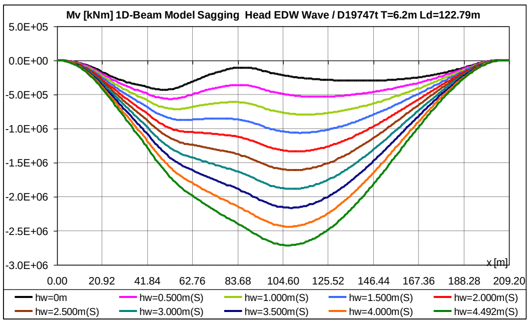

Fig. 12e. VBM, D19747t, sagg., μ=0

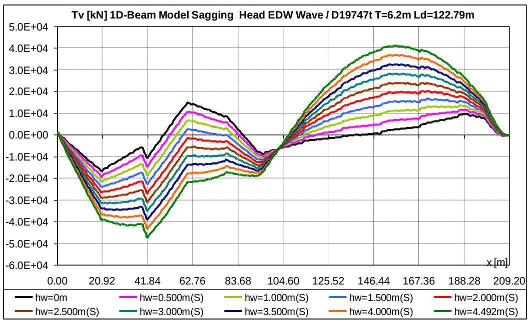

Fig. 12f. VSF, D19747t, sagg., μ=0

Table 5a. Free board criterion, DOCKV
T_m=6.2 m, F_s=0.300 m

EDW	h_w[m]	0	0.500	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.492
hogging	T_m[m]	6.200	6.191	6.182	6.174	6.165	6.156	6.147	6.138	6.128	6.118
	θ[rad]	0.00000	-0.00028	-0.00058	-0.00089	-0.00120	-0.00151	-0.00182	-0.00213	-0.00244	-0.00275
	x_F[m]	100.104	100.107	100.110	100.114	100.117	100.120	100.124	100.128	100.132	100.135
	T_{pp}[m]	6.200	6.219	6.240	6.263	6.285	6.307	6.330	6.351	6.372	6.394
	T_{pv}[m]	6.200	6.160	6.119	6.077	6.034	5.992	5.949	5.905	5.862	5.819
	F_{aft}[m]	3.900	4.131	4.360	4.587	4.815	5.043	5.270	5.499	5.728	5.952
	F_m[m]	3.900	3.661	3.420	3.180	2.940	2.700	2.461	2.222	1.983	1.748
	F_{fore}[m]	3.900	4.190	4.481	4.773	5.066	5.358	5.651	5.945	6.238	6.527
	F_{min}[m]	3.900	3.661	3.420	3.180	2.940	2.700	2.461	2.222	1.983	1.748
	F_{min}/F_s	>1	>1	>1	>1	>1	>1	>1	>1	>1	>1
sagging	T_m[m]	6.200	6.207	6.215	6.222	6.229	6.236	6.243	6.250	6.256	6.262
	θ[rad]	0.00000	0.00032	0.00063	0.00095	0.00126	0.00157	0.00189	0.00220	0.00251	0.00282
	x_F[m]	100.104	100.100	100.097	100.094	100.092	100.089	100.086	100.084	100.081	100.079
	T_{pp}[m]	6.200	6.175	6.152	6.127	6.103	6.079	6.054	6.029	6.005	5.980
	T_{pv}[m]	6.200	6.242	6.284	6.326	6.367	6.407	6.449	6.490	6.530	6.570
	F_{aft}[m]	3.900	3.675	3.448	3.223	2.997	2.771	2.546	2.321	2.095	1.874
	F_m[m]	3.900	4.142	4.382	4.624	4.865	5.107	5.349	5.591	5.833	6.071
	F_{fore}[m]	3.900	3.608	3.316	3.024	2.733	2.443	2.151	1.860	1.570	1.284
	F_{min}[m]	3.900	3.608	3.316	3.024	2.733	2.443	2.151	1.860	1.570	1.284
	F_{min}/F_s	>1	>1	>1	>1	>1	>1	>1	>1	>1	>1

Table 5b. Global strength criteria, DOCKV light displacement,
T_m=6.2m (with ballast)

EDW	h_w[m]	0	0.500	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.492
hogg	VBM_{max}	5.11E+05	3.26E+05	3.41E+05	5.96E+05	8.53E+05	1.11E+06	1.37E+06	1.63E+06	1.89E+06	2.15E+06
	max/adm	0.15	0.09	0.10	0.17	0.25	0.32	0.40	0.47	0.55	0.63
	VSF_{max}	2.11E+04	1.87E+04	2.27E+04	2.68E+04	3.08E+04	3.48E+04	3.89E+04	4.29E+04	4.69E+04	5.08E+04
	max/adm	0.37	0.33	0.40	0.47	0.54	0.61	0.68	0.75	0.82	0.89
sagg	VBM_{max}	5.11E+05	7.70E+05	1.03E+06	1.30E+06	1.57E+06	1.84E+06	2.12E+06	2.39E+06	2.67E+06	2.94E+06
	max/adm	0.15	0.22	0.30	0.38	0.46	0.54	0.62	0.70	0.77	0.85
	VSF_{max}	2.11E+04	2.36E+04	2.60E+04	2.85E+04	3.11E+04	3.36E+04	3.61E+04	3.86E+04	4.11E+04	4.40E+04
	max/adm	0.37	0.41	0.46	0.50	0.54	0.59	0.63	0.68	0.72	0.77

Table 5c. Global strength criteria, DOCKV docking 19747 t (and ballast)
Ld=0÷122.79 m h_w=0 m T_m=6.2 m

Ld[m]		steel	0	10	20	40	60	80	100	122.79
docking	VBM_{max}	3.37E+05	5.11E+05	4.14E+05	5.11E+05	4.13E+05	4.15E+05	4.06E+05	4.23E+05	4.29E+05
	max/adm	0.098	0.149	0.120	0.149	0.120	0.121	0.118	0.123	0.125
	VSF_{max}	6.13E+03	2.11E+04	1.64E+04	2.11E+04	1.64E+04	1.65E+04	1.62E+04	1.66E+04	1.68E+04
	max/adm	0.108	0.370	0.288	0.370	0.287	0.289	0.284	0.291	0.294

Table 5d. Global strength criteria, DOCKV docking D19747 t (and ballast),
Ld_{max}=122.79 m T_m=6.2m

EDW	h_w[m]	0	0.500	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.492
hogg	VBM_{max}	4.29E+05	3.07E+05	4.18E+05	6.82E+05	9.47E+05	1.21E+06	1.48E+06	1.75E+06	2.01E+06	2.28E+06
	max/adm	0.12	0.09	0.12	0.20	0.28	0.35	0.43	0.51	0.58	0.66
	VSF_{max}	1.68E+04	1.88E+04	2.29E+04	2.69E+04	3.09E+04	3.50E+04	3.90E+04	4.30E+04	4.70E+04	5.10E+04
	max/adm	0.29	0.33	0.40	0.47	0.54	0.61	0.68	0.75	0.83	0.89
sagg	VBM_{max}	4.29E+05	5.65E+05	7.95E+05	1.06E+06	1.34E+06	1.61E+06	1.89E+06	2.16E+06	2.44E+06	2.71E+06
	max/adm	0.12	0.16	0.23	0.31	0.39	0.47	0.55	0.63	0.71	0.79
	VSF_{max}	1.68E+04	1.92E+04	2.17E+04	2.42E+04	2.69E+04	3.10E+04	3.51E+04	3.92E+04	4.32E+04	4.73E+04
	max/adm	0.29	0.34	0.38	0.42	0.47	0.54	0.62	0.69	0.76	0.83

Table 5e. Global strength criteria, DOCKV D27000 t (& ballast), docked ship 1 uniform-mass distribution, T_m=6.2m

EDW	h_w[m]	0	0.500	1.000	1.500	2.000	2.500	3.000	**3.213**	**3.908**	4.492
hogg	VBM_{max}	1.28E+06	1.01E+06	7.40E+05	5.72E+05	4.34E+05	3.07E+05	4.12E+05	5.24E+05	8.92E+05	1.20E+06
	max/adm	0.37	0.29	0.22	0.17	0.13	0.09	0.12	0.15	0.26	0.35
	VSF_{max}	3.09E+04	2.69E+04	2.29E+04	1.89E+04	1.49E+04	1.89E+04	2.29E+04	2.46E+04	3.02E+04	3.49E+04
	max/adm	0.54	0.47	0.40	0.33	0.26	0.33	0.40	0.43	0.53	0.61
sagg	VBM_{max}	1.28E+06	1.55E+06	1.83E+06	2.10E+06	2.38E+06	2.66E+06	2.93E+06	3.05E+06	3.44E+06	3.77E+06
	max/adm	0.37	0.45	0.53	0.61	0.69	0.77	0.85	0.89	**1.00**	1.09
	VSF_{max}	3.09E+04	3.49E+04	3.90E+04	4.30E+04	4.71E+04	5.12E+04	5.53E+04	5.70E+04	6.27E+04	6.75E+04
	max/adm	0.54	0.61	0.68	0.76	0.83	0.90	0.97	**1.00**	1.10	1.18

Table 5f. Global strength criteria, DOCKV D27000 t (and ballast), docked ship 2 hogging-mass distribution, T_m=6.2 m

EDW	h_w[m]	0	0.500	1.000	1.500	2.000	2.500	3.000	**3.769**	4.000	4.492
hogg	VBM_{max}	9.91E+05	7.67E+05	5.61E+05	3.84E+05	4.97E+05	7.55E+05	1.01E+06	1.42E+06	1.54E+06	1.79E+06
	max/adm	0.29	0.22	0.16	0.11	0.14	0.22	0.29	0.41	0.45	0.52
	VSF_{max}	2.71E+04	2.32E+04	1.93E+04	2.30E+04	2.70E+04	3.11E+04	3.51E+04	4.13E+04	4.32E+04	4.71E+04
	max/adm	0.48	0.41	0.34	0.40	0.47	0.55	0.62	0.72	0.76	0.83
sagg	VBM_{max}	9.91E+05	1.23E+06	1.47E+06	1.73E+06	1.99E+06	2.25E+06	2.52E+06	2.93E+06	3.06E+06	3.33E+06
	max/adm	0.29	0.36	0.43	0.50	0.58	0.66	0.73	0.85	0.89	0.97
	VSF_{max}	2.71E+04	3.10E+04	3.50E+04	3.89E+04	4.29E+04	4.69E+04	5.09E+04	5.70E+04	5.89E+04	6.28E+04
	max/adm	0.48	0.54	0.61	0.68	0.75	0.82	0.89	**1.00**	1.03	1.10

Table 5g. Global strength criteria, DOCKV D27000 t (and ballast), docked ship 3 sagging-mass distribution, T_m=6.2 m

EDW	h_w[m]	0	0.500	1.000	1.500	2.000	**2.197**	3.000	**3.176**	4.000	4.492
hogg	VBM_{max}	1.68E+06	1.40E+06	1.13E+06	9.35E+05	7.80E+05	7.21E+05	5.00E+05	4.56E+05	5.11E+05	7.77E+05
	max/adm	0.49	0.41	0.33	0.27	0.23	0.21	0.15	0.13	0.15	0.23
	VSF_{max}	3.92E+04	3.52E+04	3.11E+04	2.71E+04	2.31E+04	2.15E+04	1.73E+04	1.87E+04	2.54E+04	2.93E+04
	max/adm	0.69	0.62	0.55	0.48	0.41	0.38	0.30	0.33	0.44	0.51
sagg	VBM_{max}	1.68E+06	1.96E+06	2.23E+06	2.51E+06	2.79E+06	2.90E+06	3.34E+06	3.44E+06	3.90E+06	4.17E+06
	max/adm	0.49	0.57	0.65	0.73	0.81	0.84	0.97	**1.00**	1.13	1.21
	VSF_{max}	3.92E+04	4.32E+04	4.73E+04	5.13E+04	5.54E+04	5.70E+04	6.35E+04	6.50E+04	7.17E+04	7.57E+04
	max/adm	0.69	0.76	0.83	0.90	0.97	**1.00**	1.11	1.14	1.26	1.33

Table 6. The small floating docks NWT-Dock60 and CWT-Dock60 results, in oblique waves, by equivalent beam model

Docking case	NWT Light	NWT Ship 1	NWT Ship 2	NWT Ship 3	CWT Light	CWT Ship 1	CWT Ship 2	CWT Ship 3
$h_{w\ limit}$ [m]	0.640	0.420	0.420	0.261	1.930	0.550	0.550	0.550
criterion	strength	free board	free board	strength	free board limitations at pontoon main deck			
inland	IN(0.64)	IN(0.42)	IN(0.42)	SW	IN(1.93)	IN(0.55)	IN(0.55)	IN(0.55)
costal	sheltered operation				RE(37%)	sheltered operation		

Table 7. DOCKV large floating dock results by equivalent beam models and head design waves

Docking case	Light *T*6.2	D19747t *T*6.2	D27000t hogg. *T*6.2	D27000t unif. *T*6.2	D27000t sagg. *T*6.2
$h_{w\ limit}$ [m]	4.492	4.492	3.769	3.213	2.197
criterion	no restrictions		AVSF admissible global strength, sagging EDW condition		
inland	IN(2.0)	IN(2.0)	IN(2.0)	IN(2.0)	IN(2.0)
costal	RE(50%)	RE(50%)	≈RE(40%)	≈RE(35%)	≈RE(24%)

6. CONCLUSIONS

The study of three floating docks versions leads to the following results:

1) Both small size floating docks Dock60 have a structural enhancement by considering the frames distance $a_{Fr}=a_0$=600mm, having am increased global ultimate strength (Fig.3.b, Fig.5.b, Table 2) as in initial versions [3].

2) For small size floating dock NWT-dock60, with non-continuous side ballast tanks, function to the heading angle μ=0-90° (360), the following limit wave heights are recorded: light case (Table 3a) h_{wlim}=0.640-1.278 m (strength criteria VBM hogging, μ=0÷45°) and h_{wlim}=1.800 m (free board criteria, μ=60÷90°); ship 1 and ship 2 cases (Tables 3b, c) h_{wlim}=0.420 m (free board criteria, μ=0÷90°); ship 3 case (Table 3d) h_{wlim}=0.261-0.318 m (strength criteria VBM hogging, μ=0÷30°) and h_{wlim}=0.420 m (free board criteria, μ=45÷90°). The synthesis of the operation limits for the NWT-dock60 is presented in the polar diagram of oblique EDW height (Fig. 11a) and Table 6.

3) For small size floating dock CWT-dock60, with continuous side ballast tanks, function to the heading angle μ=0-90° (360) the following limit wave heights are recorded: light case (Table 4a) h_{wlim}=1.930 m, ship 1, 2, 3 cases (Tables 4b, c, d) h_{wlim}=0.550 m, with restrictions only due to the free board criterion (μ=0÷90°). The synthesis of the operation limits for the CWT-dock60 is presented in the polar diagram of oblique EDW height (Fig. 11b) and Table 6.

4) For both floating docks Dock60 the most restrictive wave case is the head (follow) μ=0° (180°) condition, having a uniform structure over the whole length and no stress hot-spots included in the equivalent beam dock models. The NWT-Dock60 version has operation condition restrictions for inland SW÷IN(0.64) and costal must be sheltered. The CWT-Dock60 version has less operation restrictions for inland IN(0.55)÷IN(1.93) and costal can be relocated in light case RE(37%) with special approval, but must operate in sheltered conditions in any docking cases (Figs. 11a, b, Table 6). Although NWT version has more operation restrictions, it is recommended for inland harbours, being possible easier to be constructed by a conversion of a standard barge or pontoon.

5) For the large floating DOCKV [2], no restrictions are obtained by free board criterion (Table 5a). In light (Table 5b) case and during the shipyard docking scenario D19747t (Tables 5c, d), no strength restrictions are recorded, so that h_{wlim}=4.492 m with operation class inland IN(2.0) and costal RE(50%). For extreme docking cases D27000 t, the strength limits are on VSF sagging (Tables 5e, f, g), resulting hw_{him}=2.197÷3.769 m, so that for inland operation are no restrictions IN(2.0) and for costal RE(24%÷40%) requiring special approval. The synthesis of the operation limits for the DOCKV, head wave conditions are presented in Table 7. No oblique waves are considered, according to small size dock results.

6) Further studies shall include structural analysis on 3D-FEM models for the floating dock, so that the stress hot-spots can be considered, and the limits by strength criteria 3D stress state can be used.

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