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ON RIVER BARGE OF 3000 T PRELIMINARY SEAKEEPING APPROACH

Dumitru-Silviu Perijoc
"Dunarea de Jos" University of Galati,
Faculty of Naval Architecture, Galati,
47 Domneasca Street,800008, Romania,
E-mail: silviu.perijoc@ugal.ro

Leonard Domnişoru
"Dunarea de Jos" University of Galati,
Faculty of Naval Architecture, Galati,
47 Domneasca Street, 800008, Romania,
E-mail: leonard.domnisoru@ugal.ro

ABSTRACT

This study concerns the preliminary seakeeping analysis of a river barge of 3000 T with a length of 90 m and two main loading conditions: full cargo and ballast. As environmental conditions, the maximum wave height is 2 m, with a whole range wave-barge heading angle, specific for all the river navigation zone. The maximum speed of the river barge is 15 km/h. The numerical analysis involves a linear seakeeping code by strip-theory method and short-term irregular waves approach, representing a preliminary simplified evaluation of the navigation capabilities of the river barge.

Keywords: river barge, linear seakeeping, short-term analysis, irregular waves.

1. INTRODUCTION

For a river barge of 3000 T, the preliminary seakeeping analysis through linear strip-theory method [1] is developed in this study.

Table 1 presents the main characteristics of the 3000 T river barge [2], with two loading conditions: full cargo (F) and ballast (B). The river barge has an almost prismatic shape.

Table 1. The 3000 T river barge data [2].

L[m]	90	Load:	Full (F)	Ball (B)
H[m]	4.5	Δ[t]	3620.73	507.73
B[m]	11	d_{pp}[m]	3.912	0.565
stations	390	d_{pv}[m]	3.684	0.565
points	11700	d_m[m]	3.799	0.565
v[km/h]	0, 5, 8, 11, 15	x_G[m]	43.145	42.252
		x_F[m]	44.968	42.170
g[m/s^2]	9.81	z_B[m]	1.932	0.287
ρ[t/m^3]	1.025	z_G[m]	3.037	1.992
spectrum	ITTC	r[m]	2.748	18.380
$H_{s\text{-}max}$[m]	2.000	h_0[m]	1.643	16.675
μ [deg]	0÷180	T_{heave}[s]	5.457	3.692
J_{xx}[tm^2] F	32231	T_{pitch}[s]	5.102	3.828
J_{xx}[tm^2] B	9756	T_{roll}[s]	5.826	2.188

Figs.1,2 present the transversal stability charts, resulting in the peak heaving angle φ_{maxGZ} equal to 13.50 deg (F) and 23.75 deg (B).

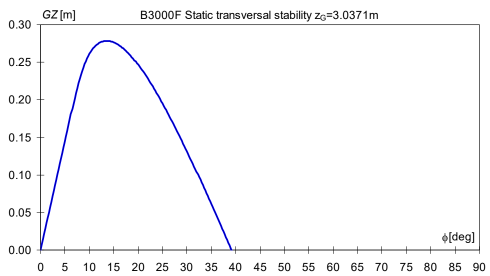

Fig.1 Barge 3000 T, GZ[m], full cargo (F).

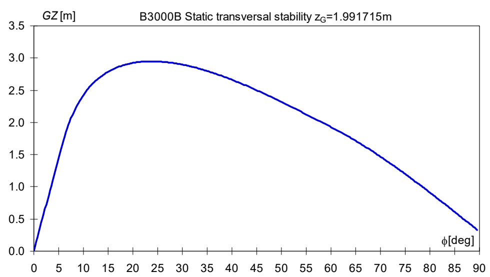

Fig.2 Barge 3000 T, GZ[m], ballast (B).

Table 2 presents the required seakeeping limit values used for the preliminary simplified evaluation of the river barge of 3000 T.

Table 2 Seakeeping limit values (adm).

Loading case	Full (F)	Ballast (B)
$RMS_{Zpp-adm}$m]	0.488	3.835
RMS_{Zm-adm}[m]	0.602	3.835
$RMS_{Zpv-adm}$[m]	0.716	3.834
$RMS_{Rpitch-adm}$[deg]	1	1
$RMS_{Rroll-adm}$[deg]	4	4
$RMS_{Zacc-heave-adm}$[m/s^2]	0.491	0.491
$RMS_{Racc-pitch-adm}$[deg/s^2]	1.248	1.175
$RMS_{Racc-roll-adm}$[deg/s^2]	10.219	15.329

The preliminary seakeeping analysis of the 3000 T river barge is done by a linear strip theory approach implemented in its own DYN(OSC) code [3], validated by several tests [4], [5].

2. FULL CARGO (F), 3000 T RIVER BARGE DYNAMIC ANALYSIS

2.1 RAO's functions of the 3000 T river barge, full cargo loading case

The linear strip theory [3] applied to the river barge of 3000 T on full cargo loading case, with unit amplitude regular wave excitation, delivers the deterministic hydrodynamic response in the frequency domain:

-Fig. 3, heave *RAO*, v=0 km/h, full;
-Figs. 4.1-5, heave *RAO*, μ=0-180 deg, full;
-Fig. 5, pitch *RAO*, v=0 km/h, full;
-Figs. 6.1-5, pitch *RAO*, μ=0-180 deg, full;
-Fig. 7, roll *RAO*, v=0 km/h, full;
-Figs. 8.1-5, roll *RAO*, μ=70-110 deg, full;

function to the v barge speed, μ heading angle, and ω wave circular frequency.

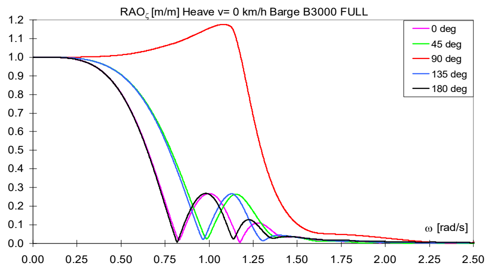

Fig.3 Heave *RAO* [m/m], v=0 km/h, (F).

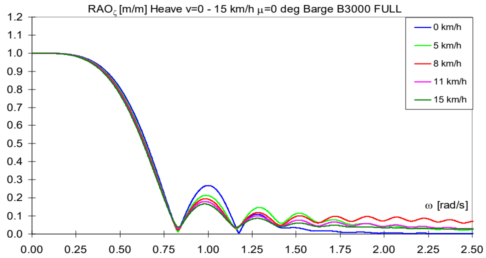

Fig.4.1 Heave *RAO* [m/m], μ=0, v=0-15 km/h,(F).

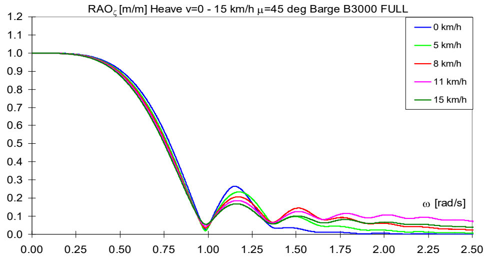

Fig.4.2 Heave *RAO*[m/m],μ=45, v=0-15km/h,(F).

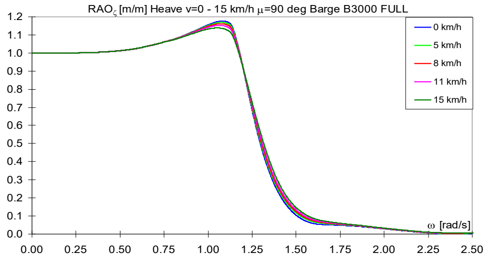

Fig.4.3 Heave *RAO*[m/m],μ=90, v=0-15km/h,(F).

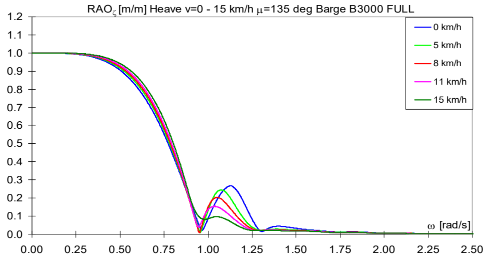

Fig.4.4 Heave *RAO*[m/m],μ=135,v=0-15km/h,(F).

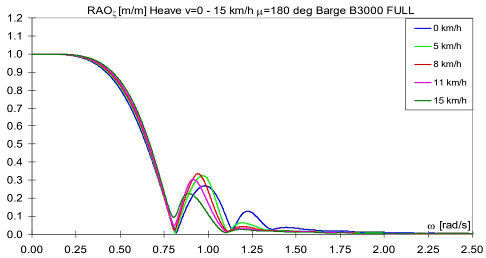

Fig.4.5 Heave *RAO*[m/m],μ=180,v=0-15km/h,(F).

The maximum heave *RAO* is obtained at beam waves. The speed influence is reduced on following and stern oblique waves, being recorded mainly on the fore oblique and head waves (Figs. 3, 4).

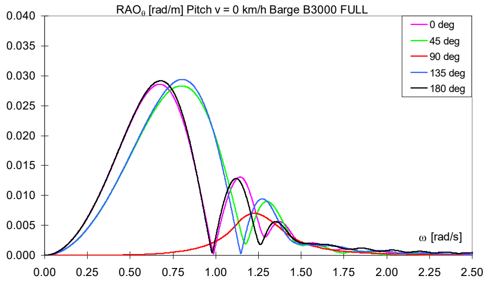

Fig.5 Pitch *RAO* [rad/m], *v*=0 km/h, (F).

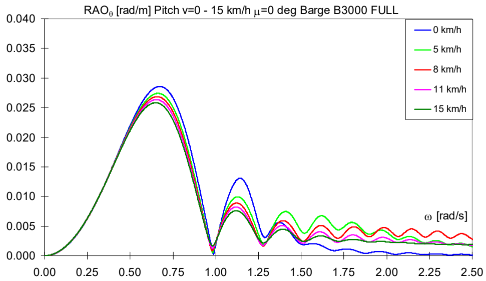

Fig.6.1 Pitch *RAO* [rad/m], μ=0, *v*=0-15 km/h,(F).

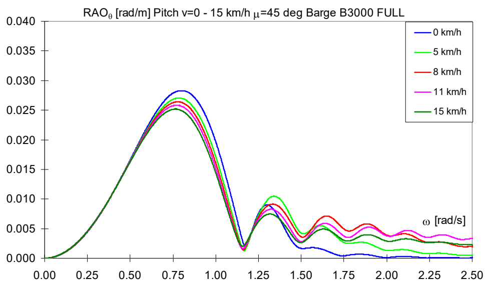

Fig.6.2 Pitch *RAO*[rad/m],μ=45, *v*=0-15km/h,(F).

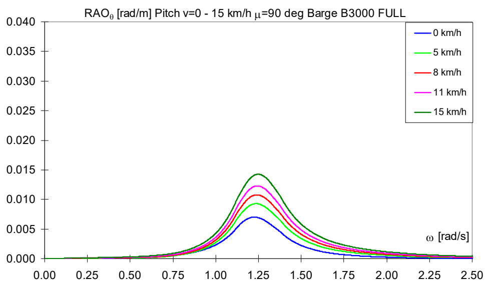

Fig.6.3 Pitch *RAO*[rad/m],μ=90, *v*=0-15km/h,(F).

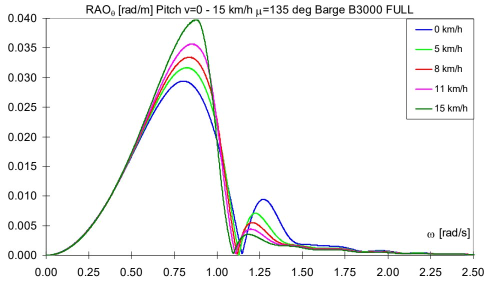

Fig.6.4 Pitch *RAO*[rad/m],μ=135,*v*=0-15km/h,(F).

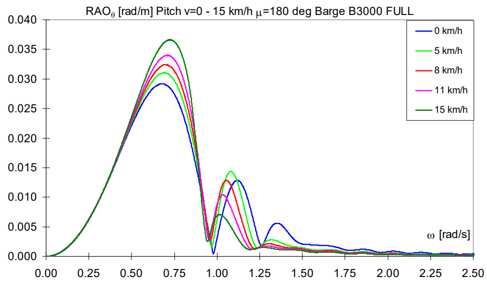

Fig.6.5 Pitch *RAO*[rad/m],μ=180,*v*=0-15km/h,(F).

The maximum pitch *RAO* is obtained at the fore oblique waves and minim at beam waves. The speed influence is recorded for all the heading angles (Figs. 5, 6).

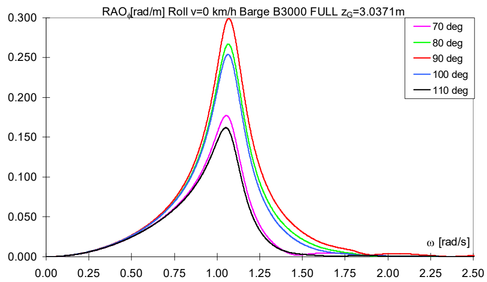

Fig.7 Roll *RAO* [rad/m], *v*=0 km/h, (F).

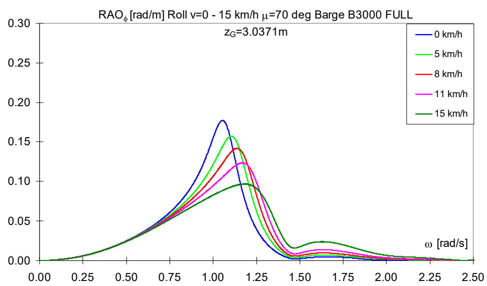

Fig.8.1 Roll *RAO* [rad/m], μ=70,*v*=0-15 km/h,(F).

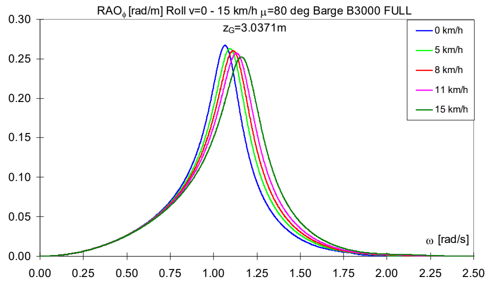

Fig.8.2 Roll *RAO*[rad/m],μ=80, *v*=0-15km/h,(F).

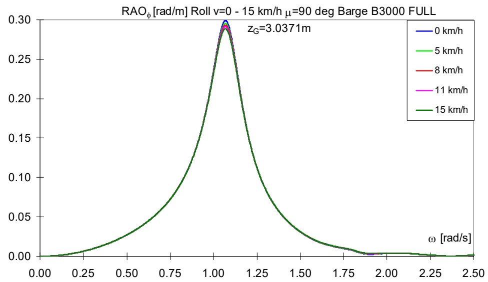

Fig.8.3 Roll *RAO*[rad/m],μ=90, *v*=0-15km/h,(F).

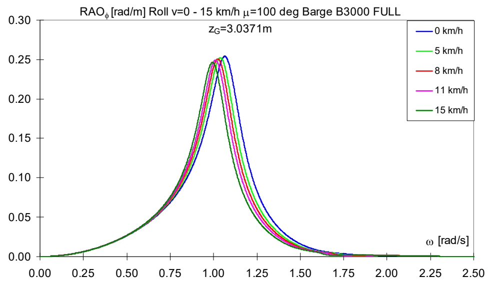

Fig.8.4 Roll *RAO*[rad/m],μ=100,*v*=0-15km/h,(F).

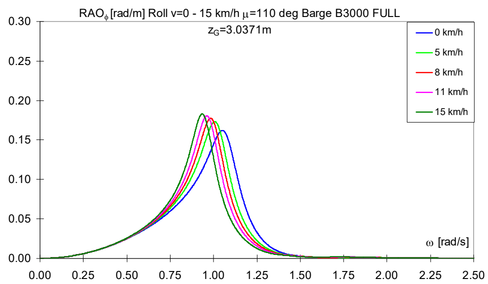

Fig.8.5 Roll *RAO*[rad/m],μ=110,*v*=0-15km/h,(F).

The maximum roll *RAO* is obtained at beam waves when there is no speed influence. For follow and head waves, roll is zero. The speed influence can be recorded for stern and fore oblique waves (Figs. 7, 8).

2.2 Short-term response of the 3000 T river barge, full cargo loading case

The short-term statistical analysis of the dynamic response approach [1], [3] applied to the river barge of 3000 T on full cargo loading case, with ITTC [3] irregular waves spectrum, delivers the most probable statistical *RMS* response for the oscillation components:

-Figs. 9.1-3, vertical combined motions, maximum short-term RMS_Z, aft (pp), mid (m) and fore (pv), v=0-15 km, μ=0-180 deg, full;

-Figs. 10.1-2, pitch and roll motions, maximum short-term RMS_R, v=0-15 km, μ=0-180 deg, full;

-Figs. 11.1-3, heave, pitch, and roll accelerations, maximum short-term RMS_{acc}, v=0-15 km, μ=0-180 deg, full.

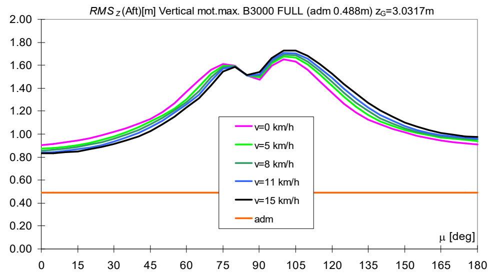

Fig.9.1 Maximum RMS_{Zpp} [m], full cargo (F).

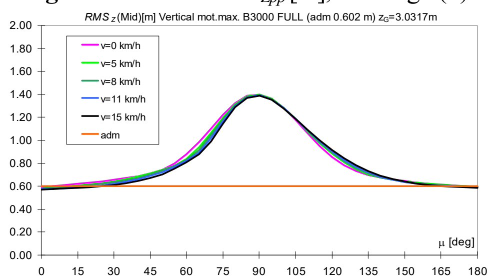

Fig.9.2 Maximum RMS_{Zm}[m], full cargo (F).

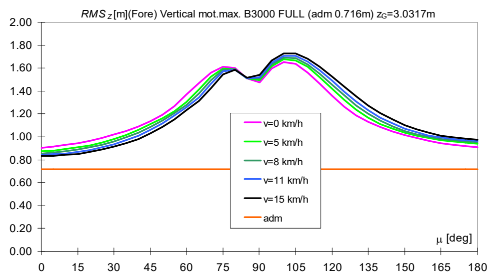

Fig.9.3 Maximum RMS_{Zpv}[m], full cargo (F).

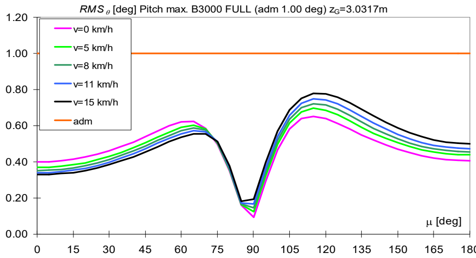

Fig.10.1 Maximum RMS_{Rpitch} [deg], full cargo (F).

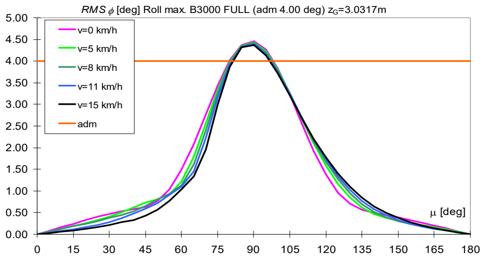

Fig.10.2 Maximum RMS_{Rroll} [deg], full cargo (F).

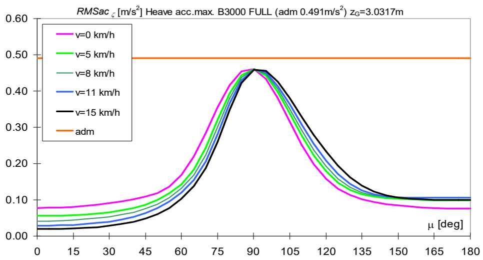

Fig.11.1 Maximum $RMS_{Zacc\text{-}heave}$[m/s^2], (F).

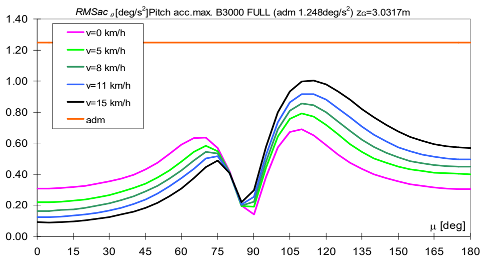

Fig.11.2 Maximum $RMS_{Racc\text{-}pitch}$[deg/s^2], (F).

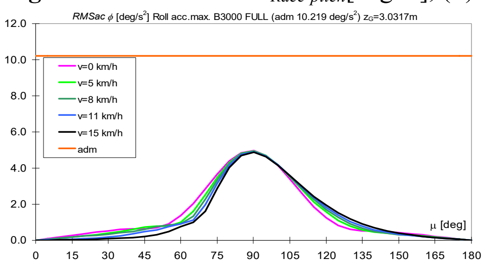

Fig.11.3 Maximum $RMS_{Racc\text{-}roll}$[deg/s^2], (F).

In the full cargo case, from the short-term statistical analysis results that the navigation restrictions occur on vertical combined motions at aft and fore for the whole range of speed and heading angles (Figs. 9.1,3), on vertical combined motions at mid-ship for the whole range of speed and μ=30-150 deg (Figs. 9.2), on roll motion for the whole range of speed and μ=75-105 deg (Figs. 10.2), without restrictions on pitch and acceleration criteria (Fig. 10.1, Fig. 11.1-3).

Combining the seakeeping criteria (Table 2) results in the preliminary seakeeping capabilities of the 3000 T river barge on full cargo case (Fig. 12), in terms of H_s significant wave height.

Table 3 presents a synthesis of the H_s limits for safe navigation of the 3000 T river barge on full cargo case (F) function to the speed in the range of 0 and 15 km/h.

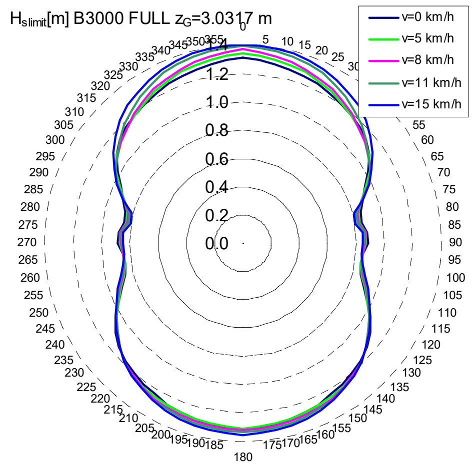

Fig.12 H_{slimit}[m], river-barge, full cargo (F).

Table.3 Preliminary seakeeping navigation limits for the 3000 T river barge, full cargo (F).

v[km/h]	H_{slimit}[m]				
μ [deg]:	0	90	180	**μ_{min}**	**min**
0	1.311	0.881	1.318	**100**	**0.841**
5	1.339	0.870	1.307	**80**	**0.840**
8	1.366	0.862	1.317	**80**	**0.830**
11	1.390	0.855	1.333	**80**	**0.819**
15	1.398	0.845	1.351	**80**	**0.804**

3. BALLAST (B), 3000 T RIVER BARGE DYNAMIC ANALYSIS

3.1 RAO's functions of the 3000 T river barge, ballast loading case

The linear strip theory [3] applied to the river barge of 3000 T on the ballast loading case, with unit amplitude regular wave excitation, delivers the deterministic hydrodynamic response in the frequency domain:

-Fig.13, heave *RAO*, v=0 km/h, ballast;
-Figs.14.1-5, heave *RAO*, μ=0-180 deg, ballast;
-Fig.15, pitch *RAO*, v=0 km/h, ballast;
-Figs.16.1-5, pitch *RAO*, μ=0-180 deg, ballast;
-Fig.17, roll *RAO*, v=0 km/h, ballast;
-Figs.18.1-5, roll *RAO*, μ=70-110 deg, ballast.

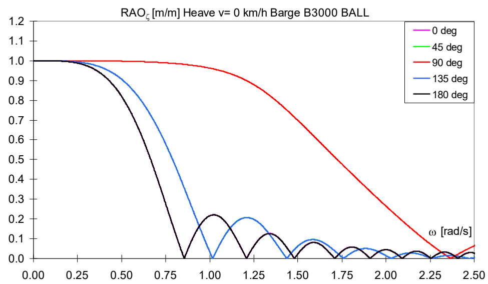

Fig.13 Heave *RAO* [m/m], v=0 km/h, (B).

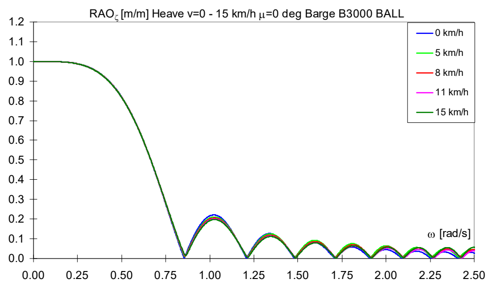

Fig.14.1 Heave *RAO*[m/m],μ=0,v=0-15 km/h,(B).

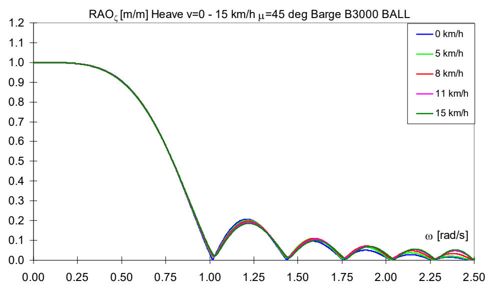

Fig.14.2 Heave *RAO*[m/m],μ=45, v=0-15km/h,(B).

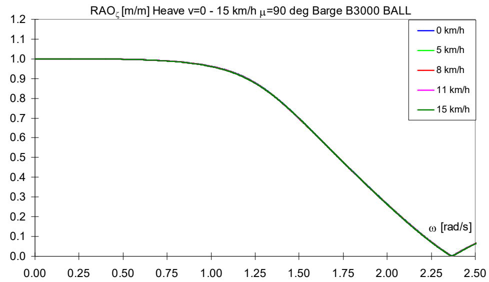

Fig.14.3 Heave *RAO*[m/m],μ=90, v=0-15km/h,(B).

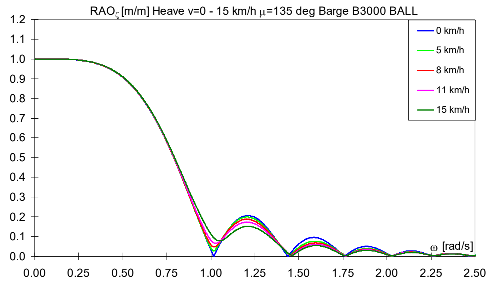

Fig.14.4 Heave *RAO*[m/m],μ=135,v=0-15km/h,(B).

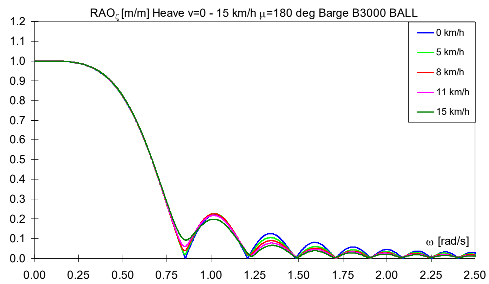

Fig.14.5 Heave *RAO*[m/m],μ=180,v=0-15km/h,(B).

Same as for the full load, the maximum heave *RAO* is obtained at beam waves. The speed influence is reduced on the whole heading angle range for the heave *RAO* (Figs. 13, 14).

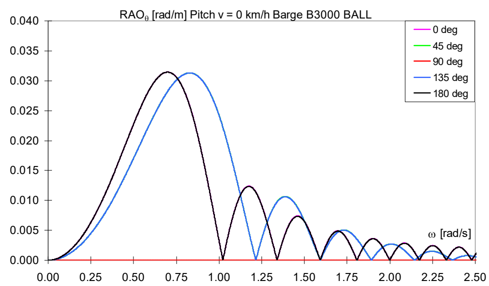

Fig.15 Pitch *RAO* [rad/m], v=0 km/h, (B).

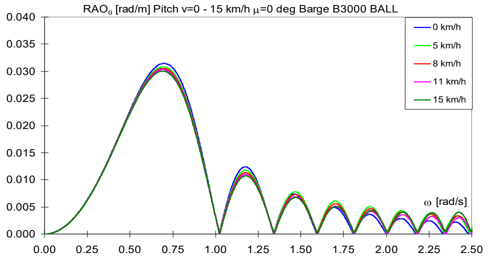

Fig.16.1 Pitch *RAO* [rad/m],μ=0,*v*=0-15 km/h,(B).

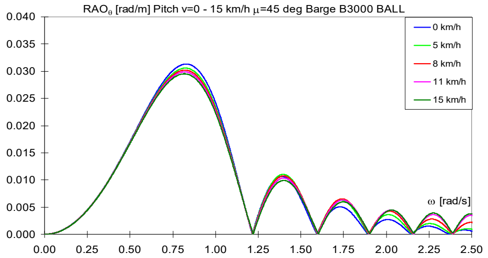

Fig.16.2 Pitch *RAO*[rad/m],μ=45,*v*=0-15km/h,(B).

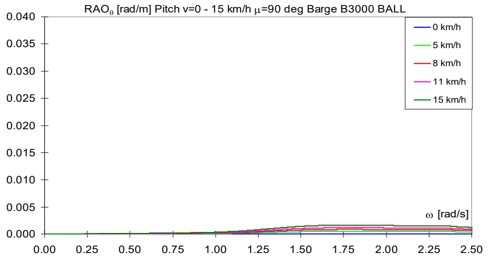

Fig.16.3 Pitch *RAO*[rad/m],μ=90, *v*=0-15km/h,(B).

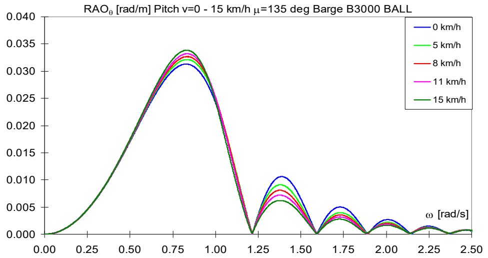

Fig.16.4 Pitch *RAO*[rad/m],μ=135,*v*=0-15km/h,(B).

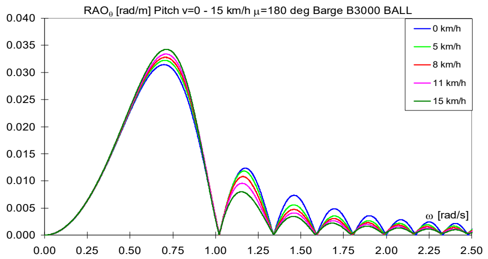

Fig.16.5 Pitch *RAO*[rad/m],μ=180,*v*=0-15km/h,(B).

The maximum pitch *RAO* is obtained at head waves and very reduced at beam waves. The speed influence is mainly for the fore oblique and head wave conditions (Figs. 15, 16).

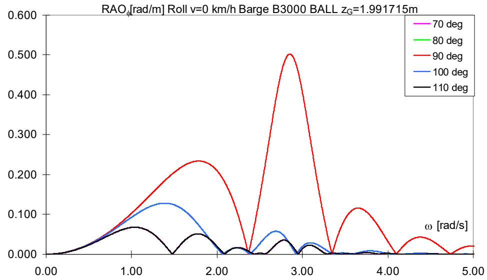

Fig.17 Roll *RAO* [rad/m], *v*=0 km/h, (B).

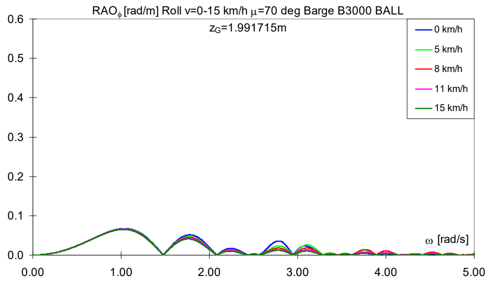

Fig.18.1 Roll *RAO* [rad/m], μ=70,*v*=0-15 km/h,(B).

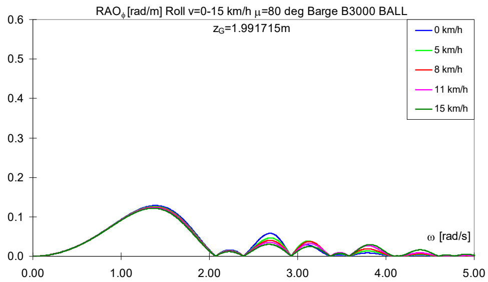

Fig.18.2 Roll *RAO*[rad/m],μ=80, *v*=0-15km/h,(B).

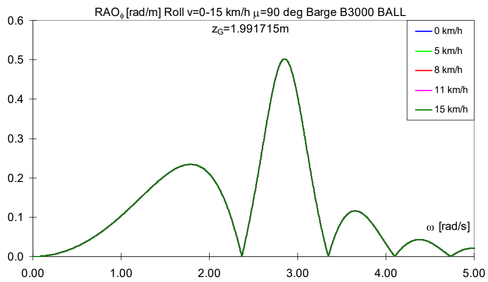

Fig.18.3 Roll *RAO*[rad/m],μ=90, *v*=0-15km/h,(B).

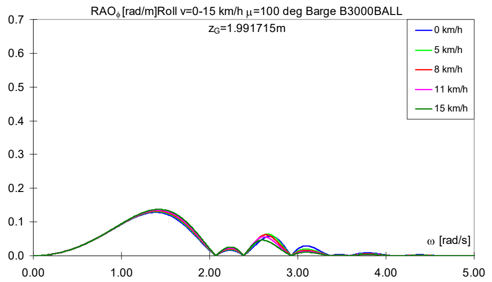

Fig.18.4 Roll *RAO*[rad/m],μ=100,*v*=0-15km/h,(B).

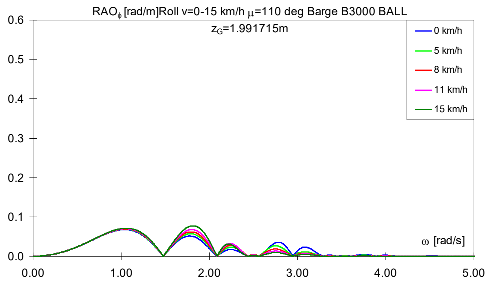

Fig.18.5 Roll *RAO*[rad/m],μ=110,*v*=0-15km/h,(B).

Same as for the full load, the maximum roll *RAO* is obtained at beam waves. For other heading angles, the roll motion is very reduced and becomes zero at follow and head waves. The speed influence is very reduced for oblique waves (Figs. 17, 18).

3.2 Short-term response of the 3000 T river barge, ballast loading case

The short-term statistical analysis of the dynamic response approach [1], [3] applied to the river barge of 3000 T on ballast loading case, with ITTC [3] irregular waves spectrum, delivers the most probable statistical *RMS* response for the oscillation components:

-Figs. 19.1-3, vertical combined motions, maximum short-term RMS_Z, aft (pp), midship (m) and fore (pv), v=0-15 km, μ=0-180 deg, ballast;

-Figs. 20.1-2, pitch and roll motions, maximum short-term RMS_R, v=0-15 km, μ=0-180 deg, ballast;

-Figs. 21.1-3, heave, pitch, and roll accelerations, maximum short-term RMS_{acc}, v=0-15 km, μ=0-180 deg, ballast.

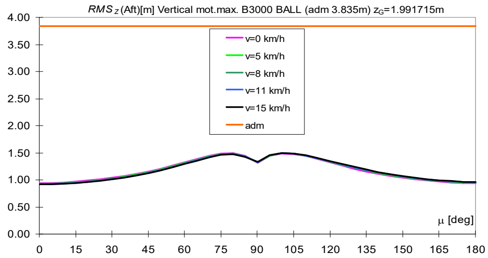

Fig.19.1 Maximum RMS_{Zpp} [m], ballast (B).

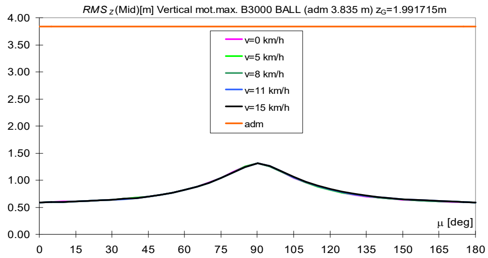

Fig.19.2 Maximum RMS_{Zm}[m], ballast (B).

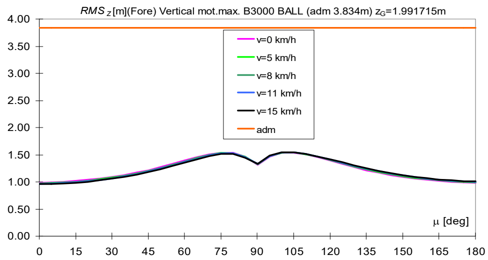

Fig.19.3 Maximum RMS_{Zpv}[m], ballast (B).

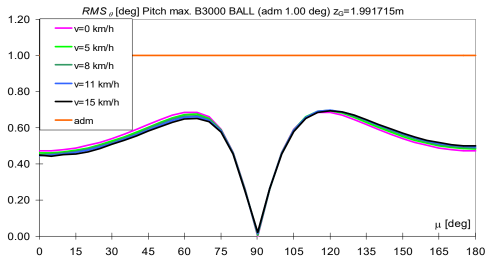

Fig.20.1 Maximum RMS_{Rpitch} [deg], ballast (B).

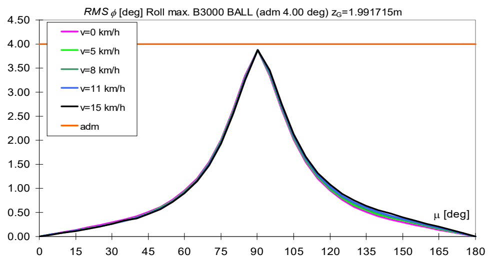

Fig.20.2 Maximum RMS_{Rroll} [deg], ballast (B).

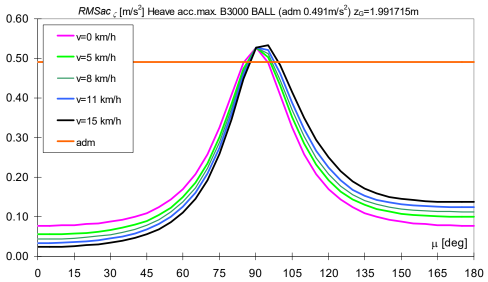

Fig.21.1 Maximum $RMS_{Zacc\text{-}heave}$[m/s^2], (B).

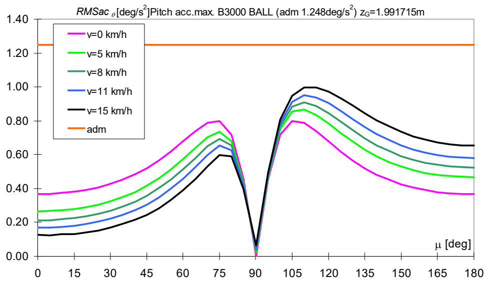

Fig.21.2 Maximum $RMS_{Racc\text{-}pitch}$[deg/s^2], (B).

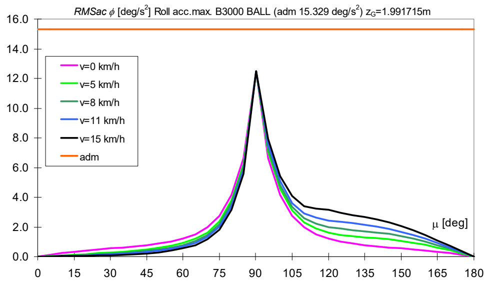

Fig.21.3 Maximum $RMS_{Racc\text{-}roll}$[deg/s^2], (B).

In the case of ballast, the short-term statistical analysis results that the navigation restrictions occur only from the heave acceleration criteria (Fig.21.1), for the whole speed range and μ=85-100 deg. The other seakeeping criteria lead to no restrictions(Figs. 19-21).

Combining the seakeeping criteria (Table 2), results in the preliminary seakeeping capabilities of the 3000 T river barge on the ballast case (Fig.22), in terms of H_s significant wave height.

Table 4 presents a synthesis of the H_s limits for safe navigation of the 3000 T river barge on ballast case (B) function to the speed in the range of 0 and 15 km/h.

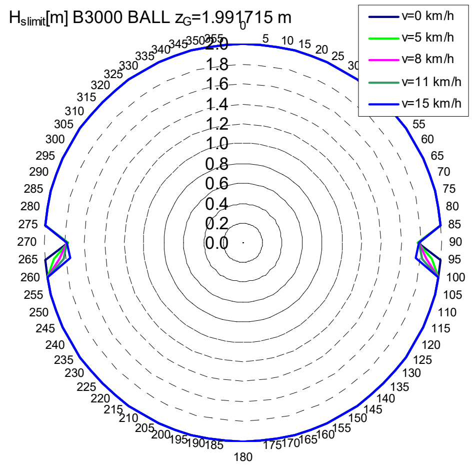

Fig.22 H_{slimit}[m], river-barge, ballast (B).

Table.4 Preliminary seakeeping navigation limits for the 3000 T river barge, ballast (B).

v[km/h]	H_{slimit}[m]				
μ [deg]:	0	90	180	**μ_{min}**	**min**
0	2.000	1.762	2.000	**90**	**1.762**
5	2.000	1.766	2.000	**90**	**1.766**
8	2.000	1.767	2.000	**90**	**1.767**
11	2.000	1.768	2.000	**90**	**1.768**
15	2.000	1.768	2.000	**95**	**1.745**

4. CONCLUSIONS

The change in the loading condition leads to different behavior in regular waves. The values of the natural oscillation periods are changed from 5.102-5.826 s on the full cargo case to 2.188-3.828 s on the ballast case (Table 1).

The navigation restrictions in irregular waves by short-term statistical analysis are different in the two loading cases of the river barge of 3000 T:

- on full cargo, the vertical combined motions and roll criteria are leading to restrictions, with H_{slimit}[m] = 0.804-0.841 m at μ ≈ 80 deg, corresponding to ≈ IN(0.8) (Table 3);
- on ballast, only the heave acceleration criteria leads to restrictions, with H_{slimit}[m] = 1.745-1.768 m at μ ≈ 90 deg, corresponding to IN(1.7) condition (Table 4).

In conclusion, the 3000 T river barge in full cargo navigation has higher restrictions as in ballast, and beam waves must be avoided.

Acknowledgments

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