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2004-2014 TEN YEARS OF CHANGING IN THE PROJECT OF PASSENGER FERRIES ON ITALIAN LAKES, DUE TO THE 2006/87/CE AND CONSEQUENT RULES

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ABSTRACT

Due to the increasing requests for the passenger transportation on internal waterways, the size of the passenger ships operating on internal water has grown significatively, requiring a different approach by the Rules for construction.
Some of the new criteria are quite different from the previous ones, especially for what concerns the damage stability, with more severe requirements about freeboard, weather criteria etc., and these criteria have impacted on the design, project, construction.
Considering these elements, here the author studies the changes required by the new rules adopted after the publishing of the Law 2006/87/CE and the consequent new Rules for Inland water .
The author examines the impact of those new requirements for stability, focusing on differences in height of the ship, transversal subdivision, position of safety appliances as rescue areas for shipwrecked people, etc. to evaluate the real effectiveness of the new rules and what has been the impact on new constructions.
To perform this analysis with a real case study, the author considers 5 ships built between 2004 and 2014, and operating on the main Italian lakes, such as Lago di Garda, Lago Maggiore and Lago di Como. The length of the ships is between 41 and 49 m, and the passenger capacity is from 420 to 700 passengers, so the stability calculation, performed and realized for each type of ships, compares the possibility for the ships realized before the new rules, to match the new requirements, the impact of modifications in case of refitting and gives a personal advice about the tendency in the future.

1. DESCRIPTION OF SHIPS EXAMINATED

The research investigated the requirements of three different classes of ship, launched on Italian Lake area over a span of about 10 years.
There are 3 classes of ship, the first of each class delivered as follows: one delivered in 2005, with a capacity of 700 passengers, one delivered in 2009 with a capacity of 460 passengers, and one delivered in 2014 with a capacity of 460 passengers.
The basic principles of each kind of ship are quite similar and as they have to operate on the same areas (Italian Lakes) and they are operated by the same company, using the same logistic support as shipyard for maintenance etc., the comparison is interesting because is it possible to isolate the differences in the design due only to the need of respecting the Class Rules.

1.1 Ship delivered in 2005

The first class, 50m – 700 pax, delivered in 2005, has the following data:
Class: RINA -MARCA STELLA 100A 1.1 TP – NAVIGAZIONE INTERNA

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L_{OA} = 50 m (with fenders)
L_{BP} = 45 m
B = 8.8m
D = 2.7m (3.35 m fore)
Lightship = 284 t (LCG=18.97 m , VCG=3.615m)
Deadweight = 69 t
Displ.F.L. = 353 t T_{ISO} = 1.81 m
N° pax = 700
V_{max} = 13.5 Kn
Fuel capacity: 11200 ltrs
Main engines : 2 x 364 kW a 1800 rpm
Propellers: 2 x Schottel STP200

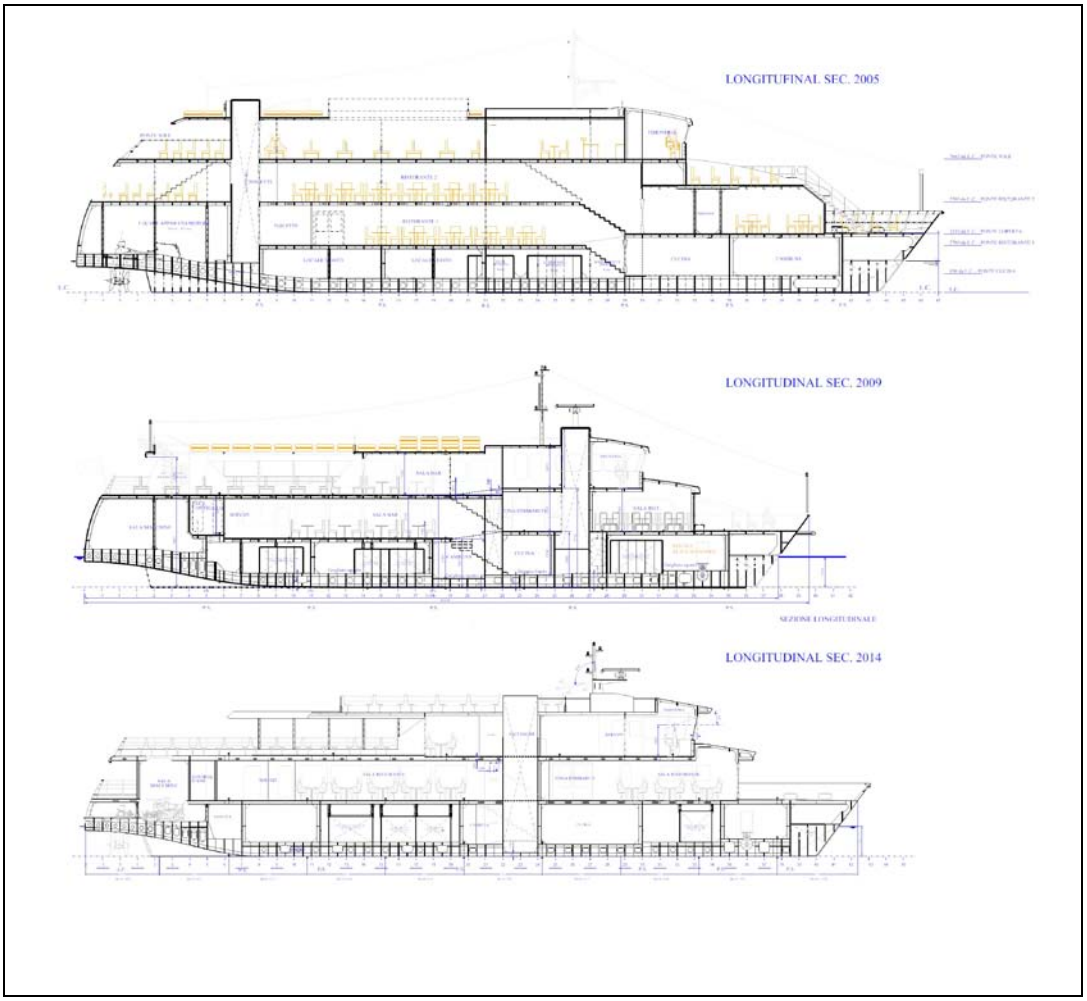

Figure 1. The 3 Classes of Ship considered

1.2 Ship delivered in 2009
The second one, 41 m – 460 pax , delivered in 2009:
Class: RINA -MARCA STELLA 100A 1.1 TP – NAVIGAZIONE INTERNA *
Main dimensions:
LOA = 41.60 m
LBP = 37.27 m
B = 8.1m
D = 2.8m
Lightship = 218.55 t (LCG=14.70 m , VCG=3.355m)
Deadweight = 70 t

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Displ.F.L. = 290 t TISO = 1.83 m
N° paxi = 460)
Vmax = 13.5 Kn
Fuel: 24000 ltrs
Main engines: 2 x 368 kW
Propellers: 2 x Schottel STP200

1.3 Ship delivered in 2014

And finally the third, 45 m - 460 pax, delivered in 2014, according to the new Rules :
Class: RINA ✠ HULL - ✠ MACH – Pass Ship – IN (2) – EFP (Pax) – DMS - IWS
L_{OA} = 45.10 m
B = 8.7m
D = 3.20 m
Lightship = 264 t (LCG=17.3 m , VCG=3.59 m)
Deadweight = 69.80 t.
Displ. F.L. = 336.16 t T_{ISO} = 1.77 m
N° pax = 460
V_{max} = 13.5 Kn
Fuel: 25000 ltrs
Main engines: 2x 364 Kw a 1800 rpm
Propellers: 2 x Schottel STP 200

2. INTACT STABILITY

As already mentioned, the main problem for the projects was the different criteria for Intact and Damaged stability introduced by the new European Rules, and the subsequent adopted Class Rules, that are more severe than before.
In this chapter we will consider basically the differences as for the Intact stability, as considered and calculated for each of the ships.
We investigated and described here only the requirements for this particular type of ship, and not the general similar to SOLAS, so for the Ships 2005 and 2009 the Rules for “Navigazione acque Interne” and for the Ship 2014 the RINA “Rules for the Classification of Inland Waterway Ships and for Conformity to Directive 006/87/EC” part B, Vol. 1 , Ch. 6 .
The Rules are the ones applied in the Stability Booklets of each ship delivered.
Obviously the requirements were to calculate the stability in the less favourable conditions, i.e. with all the passengers on board, assuming that all the passengers not seating are crowding on the higher deck , and with load conditions for the liquids as Fuel, fresh water, etc. varying from 98% of tanks full of fuel, fresh water etc. to 10% . The fact that the ships are operating in the same areas, using the same stations, with a similar speed and range etc. makes small differences in fuel loaded, fresh water etc., and not effecting a lot on the final displacement, so it is possible to compare the results.
The main criteria of stability for Ship 2005 and Ship 2009, (always referring to the special criteria for this situation, and not to the general ones) of relevance for those ships, basically require to have in all the load conditions :
Minimum GMT > 0.3 m.
With all the passengers on a side the freeboard at equilibrium angle must be:
Freeboard > 0.2 mt.
In the following figures will be showed the results of the stability calculations for each type of ship, and after the figures there will be a comparison among the different values of GMT for each type of ship in similar conditions, obviously due to the numbers of final data available and composing the “Stability booklet” of each ship, only a summary of the main relevant information has been reported, to indicate the main criteria to respect and the corresponding results

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2.1 Intact stability results Ship 2005 (49 m)

VERIFICHE DI STABILITA' A NAVE INTEGRA
Regolamento RINA 1997, norme relative alla stabilità delle navi
Capitolo 2.3: Navi da passeggeri abilitate a navigazione marittima nazionale entro acque tranquille o a navigazione lagunare
Capitolo 2.4: Navi da passeggeri abilitate a navigazione interna

	Δ PC	T iso	Assetto			VCG	GM T	
			T_{AD} (oss.0)	T_{AV} (oss.44)	T_{AD}-T_{AV}		MIN.richiesto	effettivo
	[t]	[m]	[m]	[m]	[m]	[m]	[m]	[m]
LIGHT SHIP	284,0	1,592	1,707	1,418	0,289	3,609	0,300	2,532
FL 100	352,5	1,811	1,914	1,658	0,256	4,073	0,300	1,549
FL 10	343,3	1,782	1,908	1,594	0,314	4,131	0,300	1,545
LS 10	293,0	1,620	1,718	1,472	0,246	3,528	0,300	2,517

	addensamento pax a murata						
	Δ PC	Δ equil.	bordo libero residuo				GM T
		calcolato	$MIN_{RICHIESTO}$	oss.8	oss.22	oss.29	effettivo
	[t]		[m]	[m]	[m]	[m]	[m]
FL100 - [700pax]	352,5	8.22°	0,200	0,242	0,288	0,330	1,576
FL10 - [700pax]	343,3	8.57°	0,200	0,234	0,298	0,349	1,520
FL100 - [650pax]	349,0	7.87°	0,200	0,265	0,331	0,382	1,588
FL10 - [650pax]	339,8	8.21°	0,200	0,257	0,341	0,402	1,530
FL100 - [600pax]	345,5	7.14°	0,200	0,326	0,398	0,450	1,651
FL10 - [600pax]	336,3	7.44°	0,200	0,321	0,411	0,472	1,596

Figure 2.Results of stability – ship 2005

2.2 Intact stability results Ship 2009 (41 m)

	DISL.PC	T iso		Assetto		VCG	GMT	
			T_{AD} (oss.0)	T_{AV} (oss.37)	T_{AD}-T_{AV}		MIN.richiesto	Effettivo
	[t]	[m]	[m]	[m]	[m]	[m]	[m]	[m]
1-LIGHTSHIP	218,5	1,54	1,82	1,08	0,74	3,36	0,300	2,34
2-FL100	290,2	1,83	2,13	1,34	0,79	3,52	0,300	1,56
3-FL10	271	1,75	1,97	1,40	0,57	3,65	0,300	1,54
4-FL100 esercizi	290	1,83	2,16	1,32	0.83	3,45	0,300	1,61
5-LS10	236,4	1,61	1,84	1,24	0.60	3,23	0,300	2,25
ADDENSAMENTO	PAX	A	MURATA					
			B.L.					
	DISL.	Ang.equilibrio	Min	Oss.5	Oss.26	Oss.35	GMT effettivo	
FL100	283,1	5,29s	0,200	0,45	1,26	1,57	1,72	
FL10	264	5,68s	0,200	0,56	1,24	1,51	1,69	
FL100esercizi	-	-	-	-	-	-	-	
LS10	-	-	-					

Figure 3. Results of stability – ship 2009

As for the ship delivered in 2014, the criteria are different: not only the stability must be calculated with all the passengers crowded on one side, but it must be considered also the

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heeling moment due the wind, and the heeling moment due to a turn at maximum speed, and a possible combination of the two.

2.3 Intact stability for ship 2014:
Not only the conditions of “load” (where with the word load I consider also the Heeling Moment) are different, but also the criteria to meet are more severe, the limits of Heel and equilibrium angle are different, and there is a limit also on the righting arms area.
The main requests are:
Minimum GMT > 0.3 m
Area RAH between 0°-FLD° > 0.065
All passengers on a side: Heel angle < 10°
All passengers on a side + HMMT due to wind or turning

	DISL.PC	T iso		Assetto		VCG	GMT (nave diritta)	Area tra 0-Φfld	Pag.	Cond. "b" Ang. max	Pag.	Cond. "c"	Pag.
			T_{AD}	T_{AV}	T_{AD}-T_{AV}		[illegible] 0,3 m	(> 0.065)		< 10°		B.L.	
	[t]	[m]	[m]	[m]	[m]	[m]	[m]						
1-LIGHTSHIP	264	1,52	1,58	1,44	0,26	3,59	2,68	0.33	6				
2-FL100-	335	1,76	1,76	1,77	-0,01	3,69	1,98	0.19	10	6.72°	18	0.74	22
3-FL50-	328	1,74	1,80	1,65	0,15	3,71	1,98	0.20	26	6.92°	34	0.74	38
4-FL10-	325	1,80	1,85	1,55	0,30	3,75	1,95	0.20	42	7.16°	50	0.60	54
5-LS10	290	1,61	1,70	1,48	0,22	3,41	2,57	0.32	57				
6-LS10R	267	1,55	1,59	1,49	0,10	3,53	2,62	0.31	60				

Figure 4. Intact stability

It is possible to see the differences in the values: all the ships pass the criteria, with an average “safety margin” of 10% of the required values.
In the various situations we have:
Full load
Ship 2005 GMT = 1,55 m
Ship 2009 GMT = 1,56 m
Ship 2014 GMT = 1,98 m
It’s immediate to note the wide difference.

3. DAMAGE STABILITY

The flooded stability is where we have the biggest differences in criteria: mainly because it must be considered an unsymmetrical situation due to the request of considering the crowding of passengers on one side.
In this way, we had for the Ships 2005 and 2009 the following criteria to respect:
Ship 2005 and 2009 :
Minimum GMT > 0.05 m.
Freeboard > 3”
But as for Ship 2014 , as we’ll see, the situation is different.

3.1 Ship 2005: Damage stability calculations
The following figures will show the results of the damage stability, as for request of Rules the stability has been computed in the conditions of Full load departure (100% of pax onboard and tanks full with Fuel, fresh water etc., each tank filled at 98% to maximize FSM effect) , and Full load arrival with 100% of passengers on board but 10% of Fuel and fresh water.

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caso di falla PIENO CARICO PARTENZA - 700pax					
FL100	BL_{res}			GM_T	
comp. allag.	MIN.richiesto [m]	oss.8 [m]	oss.29 [m]	MIN.richiesto [m]	effettivo [m]
1	**0,076**	**0,191**	**1,061**	0,050	**0,828**
2	**0,076**	**0,401**	**0,814**	0,050	**1,058**
3	**0,076**	**0,588**	**0,705**	0,050	**1,135**
4*	**0,076**	**0,721**	**0,601**	0,050	**1,201**
5 & 6	**0,076**	**0,888**	**0,383**	0,050	**1,582**
7	**0,076**	**0,839**	**0,935**	0,050	**1,565**

caso di falla PIENO CARICO ARRIVO - 700 pax					
FL10	BL_{res}			GM_T	
comp. allag.	MIN.richiesto [m]	oss.8 [m]	oss.29 [m]	MIN.richiesto [m]	effettivo [m]
1	**0,076**	**0,207**	**1,109**	0,050	**0,807**
2	**0,076**	**0,419**	**0,865**	0,050	**1,040**
3	**0,076**	**0,616**	**0,757**	0,050	**1,113**
4*	**0,076**	**0,698**	**0,589**	0,050	**1,196**
5 & 6	**0,076**	**0,907**	**0,448**	0,050	**1,575**
7	**0,076**	**0,860**	**0,984**	0,050	**1,559**

caso di falla NAVE SCARICA con 10% cons.					
LS10	BL_{res}			GM_T	
comp. allag.	MIN.richiesto [m]	oss.8 [m]	oss.29 [m]	MIN.richiesto [m]	effettivo [m]
1	**0,076**	**0,564**	**1,209**	0,050	**1,728**
2	**0,076**	**0,649**	**1,013**	0,050	**1,944**
3	**0,076**	**0,820**	**0,911**	0,050	**1,993**
4*	**0,076**	**0,910**	**0,773**	0,050	**2,118**
5 & 6	**0,076**	**1,093**	**0,623**	0,050	**2,354**
7	**0,076**	**1,039**	**1,119**	0,050	**2,522**

Figure 5.Results of flooded stability – Ship 2005

The report shows all the results, and is interesting to note the difference between the minimum GMT required by the Rules and the value achieved to meet other criteria : 0.05 m vs a value larger than 1.5 m.
Also the freeboard has a significative difference between the minimum value and the achieved. It is important also to consider, speaking of “Internal water” the requirements for Freeboard due to the logistic of the various mooring points, and change of water level due to seasonal aspects.

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3.2 Ship 2009 :Damage stability calculations

1) caso di falla PIENO CARICO PARTENZA -460 pax					
FL100 comp. allag.	BL_{res}			GM_T	
	Min.richiesto [m]	Oss. 5 [m]	Oss. 35 [m]	Min.richiesto [m]	effettivo [m]
1	0,076	0,11	2,35	0,050	0,91
2	0,076	0,35	1,88	0,050	0,99
3	0,076	0,41	1,50	0,050	0,98
4	0,076	0,53 (oss21)	0,86	0,050	1,10
5	0,076	0,86 (oss21)	0,85	0,050	1,60
6	0,076	0,75	1,78	0,050	1,57
2) caso di falla PIENO CARICO ARRIVO -460 pax					
FL10 comp. allag.	BL_{res}			GM_T	
	Min.richiesto [m]	Oss. 5 [m]	Oss. 35 [m]	Min.richiesto [m]	effettivo [m]
1	0,076	0,38	2,15	0,050	0,88
2	0,076	0,31	1,75	0,050	1,00
3	0,076	0,57	1,47	0,050	0,94
4	0,076	0,59 (oss21)	0,84	0,050	1,06
5	0,076	0,72 (oss21)	0,89	0,050	1,59
6	0,076	0,88	1,73	0,050	1,55
3) caso di falla NESSUN PAX - PARTENZA					
FL100 comp. allag.	BL_{res}			GM_T	
	Min.richiesto [m]	Oss. 5 [m]	Oss. 35 [m]	Min.richiesto [m]	effettivo [m]
1	0,076	0,36	2,43	0,050	1,54
2	0,076	0,58	2,05	0,050	1,69
3	0,076	0,61	1,69	0,050	1,65
4	0,076	0,74 (oss.21)	1,09	0,050	1,72
5	0,076	0,86 (oss.21)	1,14	0,050	2,31
6	0,076	0,90	1,95	0,050	2,24
4) caso di falla NESSUN PAX - ARRIVO					
FL10 comp. allag.	BL_{res}			GM_T	
	Min.richiesto [m]	Oss. 5 [m]	Oss. 35 [m]	Min.richiesto [m]	effettivo [m]
1	0,076	0,62	2,26	0,050	1,54
2	0,076	0,59	1,95	0,050	1,68
3	0,076	0,75	1,66	0,050	1,66
4	0,076	0,80 (oss.21)	1,07	0,050	1,72
5	0,076	0,93 (oss.21)	1,18	0,050	2,35
6	0,076	1,03	1,90	0,050	2,26

Figure 6. Damage stability

3.2 Ship 2014: Damage stability calculations

As above anticipated, here the criteria are different: we must consider the crowding of the passengers on one side, the limits to be reached are tighter, with limitations on the area of Rah also, and the calculations must be done also for intermediate steps of flooding of each compartment: 25%,50%,75%.
Resuming we have as requests:
Passenger on one side: asymmetrical flooding
Freeboard > 0.1 m
Angle of equilibrium < 10°
Rah area > 0.0025 m/rad from equilibrium to flooding
Here we report only the final calculations, for the Full load and Arrival conditions.

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Compartimento	Bordo libero min (m)	CRTPT corrispondente	Angolo eq.effettivo	Braccio di stabilità max (m)	Area sino all'allagamento m*rad	Angolo all.	GMT	Pagina report
Comp1-AM	0,54	1	6.8°	0,23	> 0,04	24°	1,26	77
Comp2-GE	0,47	1	5.8°	0,26	> 0,05	22°	1,50	93
Comp 3	0,62	1	6,7°	0,19	> 0,04	24°	1,30	109
Comp 4	0,109	8	5,7°	0,11	> 0,006	11°	1,40	125
Comp 5	0,97	8	4,4 °	0,33	> 0,08	25°	1,84	141
Comp 6	1.02	5	4,3°	0,36	> 0.10	27°	1.92	157
Comp 7	1.07	5	4.4°	0.32	> 0.11	29°	1.90	173

Figure 7.Results full load-ship 2014

Compartimento	Bordo libero min (m)	CRTPT corrispondente	Angolo eq.	Braccio di stabilità max (m)	Area sino all'allagamento	Angolo all.	GMT	Pagina report
Comp1-AM	0,32	1	7,3°	0,20	> 0,03	22°	1,19	303
Comp2-casse	0,31	1	6,4°	0,24	> 0,03	20°	1,44	319
Comp 3	0,47	1	7,5°	0,17	> 0,03	24°	1,24	335
Comp 4	0,27	8	6,3°	0,15	> 0,01	14°	1,37	351
Comp 5	1,0	5	4,9°	0,35	> 0,09	27°	1,86	367
Comp 6	1.08	5	4,6°	0,39	> 0.12	30°	1,94	383
Comp 7	1.01	1	4.8°	0.38	> 0.12	32°	1,92	399

Figure 8. Results arrival-ship 2014

We can resume , for the full load condition, the differences in GMT in each situation of flooding of compartments:

Full Load	2005	2009	2014
Comp1	0,83	0,9	1,26
Comp2	1,06	0,99	1,5
Comp3	1,14	0,98	1,3
Comp4	1,2	1,1	1,4
Comp5	1,58	1,6	1,84
Comp6	1,56	1,57	1,9

Figure 9. GMT for each kind of ship

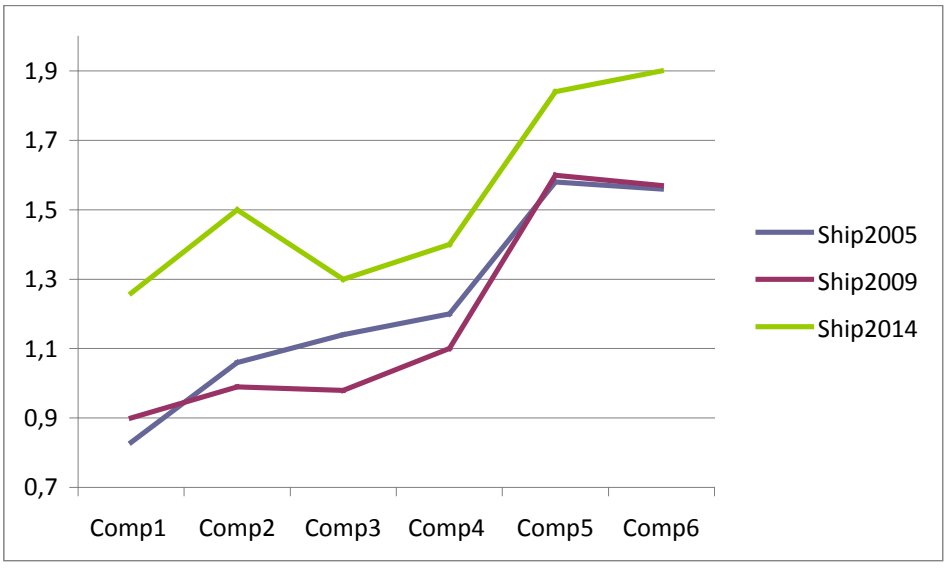

Figure 10. GMT as graph

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It's immediate to evaluate how, even with an higher hull, which raise the CG of the superstructure, the 2014 ship has a higher value of GMT, required to meet the criteria.

4. CONSIDERATIONS ABOUT THE RESULTS AND ANALYSIS

Let's consider now the main differences required to the projects to achieve the results, it is immediate to evaluate the difference in:

Ship 2005: L/B = 5.6
Ship 2009: L/B = 5.10
Ship 2014: L/B = 5.17

Ship 2005 , D = 2.8 m. T = 1.81 m.
Ship 2009 , D = 2.8 m. T = 1.83 m.
Ship 2014 , D = 3.20 m T = 1.77 m.

Ship 2005: 50 m. LOA – N. watertight compartments = 7
Ship 2009: 41 m. LOA – N. watertight compartments = 6
Ship 2014: 45 m. LOA – N. watertight compartments = 7

Ship 2005: Lightship displacement = 284 t
Ship 2009: Lightship displacement = 218 t
Ship 2014: Lightship displacement = 264 t.

The class of ships 2005 with a 10% more of length and the same Beam (8.7-8.8 m) can carry 700 passengers instead of 460, due to the use of an upper deck area, as it is possible to see from the two profiles .
Ship 2009 carries the same number of passengers of Ship 2014, but she has a D of 10% lower (2.8 amidship instead of 3.2) a B of 10% lower (8.1 vs 8.7 m) and (less than a 20% of difference in displacement).

5. 2014 CRITERIA APPLIED TO 2009 SHIP

In order to better evaluate the difference between the 2 classes of Rules applied, the stability calculation has been performed, for both intact ship and damaged ship, for the Ship model 2009 , but applying the same criteria required for the Ship 2014.
It has been decided to investigate only the Ship 2009 and not the 2005, simply because 2009 and 2014 have the same number of passengers boarded: 460.
Under the following condition:
Intact stability
a)Passengers on one side
b)Passengers on side + Heeling moment due to Wind
c) Passengers on side + Heeling moment due to Wind and Turning.
The ship matches the criteria, without simply a reduction of the freeboard in the condition c), because the freeboard, even if it is still > 0 is of 280 mm in the worst situation, with a decrease compared with the Ship 20014 where the corresponding value is always around 600-650 mm.
The situation changes in the Damaged stability calculations, in those cases , the requirement of having all the passengers crowded on one side, makes the situation more severe.
As for the ship 2009 , it is important to say: she doesn't capsize or sank…but the margin line and the deck edge go underwater, in the aft area, of about 80-280 mm no flooding point goes underwater, and the GMT remains always > 1.0 m.

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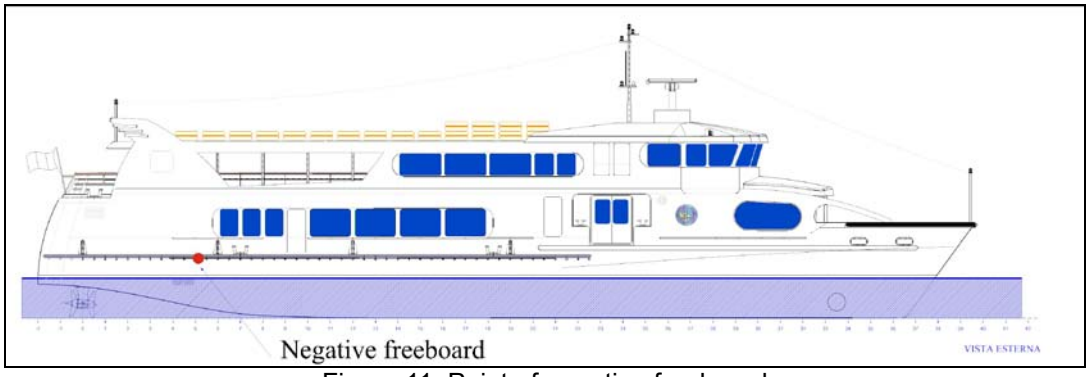

Figure 11. Point of negative freeboard

Also the area of GZ curves does not fulfil the minimum requirements, so it is not enough to simply increase the height of the hull, as done, to realize the condition of respect of freeboard, but is also necessary to increase the beam, in order to increase KMT.

6. CONCLUSIONS

It is possible to conclude that the adoption of new rules required a significant change in the project, with a difference in main dimension of impact, as can be seen by the data regarding displacement. The Ship 2014 is wider, higher and then obviously heavier, with a larger displacement, even if the Rules “ante 2009” don’t gave as result a dangerous ship, because we have seen how the Ship 2009 can still have a certain degree of safety, still the improvement is expensive.

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