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Critical deck Permeability for the Survivability of a Damaged ROPAX

Dimitris A. Spanos*

In summary

The research results on the effect of the permeability on the survive wave height for a damaged ROPAX ship are summarized in the next pages. It was found that the assumed permeability for the car deck may strong affect the residual stability and the survive wave height in sequence. The present theoretical finding should be further validated with tank tests. This work was defined and carried out within the framework of a study for European Maritime Safety Agency.

General

This research has been defined and carried out within the framework of EMSA study [1], which concerns the study of specific damage stability parameters of Ro-Ro passenger vessels. In particular it was conducted within WP2 (survivability assessment).

The ship data and specification of the damage case were provided by SSRC (Ship Stability Research Center of Glasgow University). The interest for the particular ship and damage case resulted after the preliminary assessment of the survivability with SOLAS'09 by SSRC (first task in WP2).

The necessity to investigate the effect of permeability has been established during the discussions for the scope specialization of the second task of WP2 between NTUA-SDL and SSRC.

The ROPAX vessel and Damage Case

The studied ship is a small ROPAX vessel (Lpp=104.4 m, T=4.5 m and Displ.=5500 tn) with a flat vehicle deck surrounded by side casings, as detailed in Appendix. This vessel corresponds to the *Ship1* or *EMSA1* of EMSA study.

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* Dr. Eng., Researcher, Ship Design Laboratory of the National Technical University of Athens

The assumed damage is a two-compartment damage case amidships as outlined in Figure 1 below, and detailed in Appendix. This damage case was one of the worst critical cases under SOLAS2009 and corresponds to the damage case with the code name *DS/R7_P6-7.4.0* in the provided ship data.

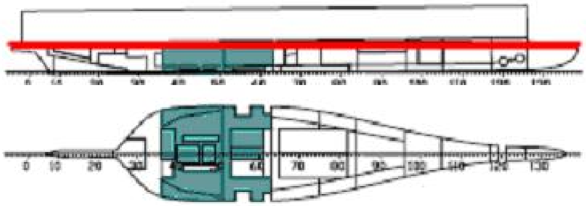


Figure 1 *The midship damage case (SSRC drawing)*

For the intact vessel a loading condition with KG=8.892 m was assumed which corresponds to a GM=1.38 m. The ship loading condition and other particulars are detailed in Appendix.

Study objective

The residual stability of the damaged ship is significantly affected by the assumed permeability for the vehicle space. This effect is demonstrated in Figure 2, where the vanishing of the *GZ* around 16 deg heeling and for a permeability of μ=0.95 (red line) is significantly shifted above 40 deg for a reduced permeability of μ=0.90 (blue line). It appears that *GZ* curve moves upwards due to the assumed remaining buoyancy within the vehicle space, which is 5% and 10% of the volume respectively.

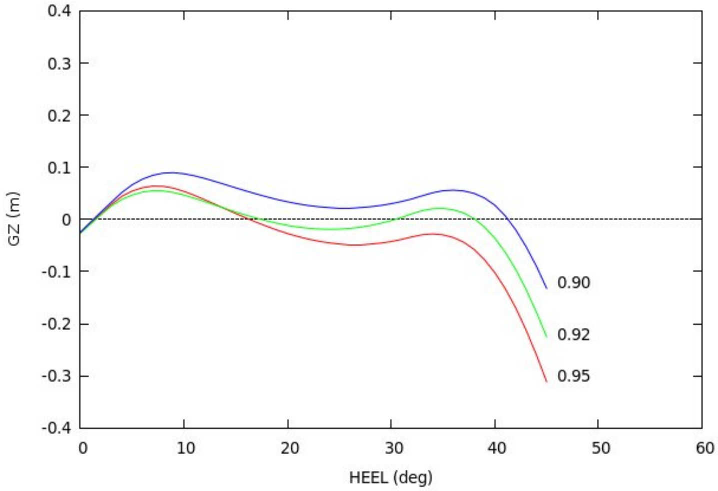


Figure 2 *GZ curves for the damaged vessel with parameter the deck permeability*

According to the above behavior the damage stability seems to change phase within a narrow band of the assumed permeability. This 5% of the homogenously distributed buoyancy over the car space is enough to result to large change in the stability range.

It is clarified that above permeability pertains to the car space, namely the blue area of the illustrative Figure 3. The side casings are assumed to remain intact after the damage and with a permeability μ=0.00. Whereas, if a single unified value would be assumed for the full space above the car deck, namely without separating the side casings, then that value would be close to μ=0.80.

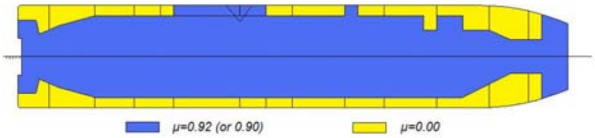


Figure 3 *Spaces on the car deck of different permeability*

The permeability of μ=0.92 (see Figure 2) appears to be a critical value between the short range and the large range residual stability. Besides, the maximum *GZ* does not increase accordingly.

The main objective of this investigation was to focus in this critical region and get insight for the corresponding survive wave height. In particular

> *Should the survive waves change gradually due to the gradual change of the permeability (and GZ_{max}), or some large change due to the abrupt increase of the stability range?*

Two assessments of the survivability in waves for the damaged ROPAX would give enough information to clarify this point. Initially the critical permeability of μ=0.92 would be assessed. Then depending on these initial results either the higher μ=0.95 or the lower μ=0.90 would be tested, taking into account that most likely the lower the permeability the higher the survivability should be. At the end a trend of the survive wave height over the permeability would have been evaluated.

If this trend were reasonably low then the survivability would be dominated by the permeability and $GZ_{\max}$, whereas for a large trend the survivability should be dominated by the range of residual stability.

Survive Wave Height

The survive wave height for the damaged ROPAX vessel is herein estimated with numerical simulations, which are based on the modeling introduced in [3]. The survive height $H_{s,surv}$ was estimated on the basis of five (5) succeeding survive tests and with a search step of δH_s=0.25 m. While survive was evaluated at 30 min from the damage event.

Two estimations carried out, assuming μ=0.92 and μ=0.90 for the permeability of the vehicle deck. Initially the case of 0.92 resulted a survive wave height $H_{s,surv}$=1.25 m. Then the value of 0.90 studied expecting to record a higher wave height (as illustrated above), which was indeed much higher $H_{s,surv}$=3.00 m, and shown in Figure 4.

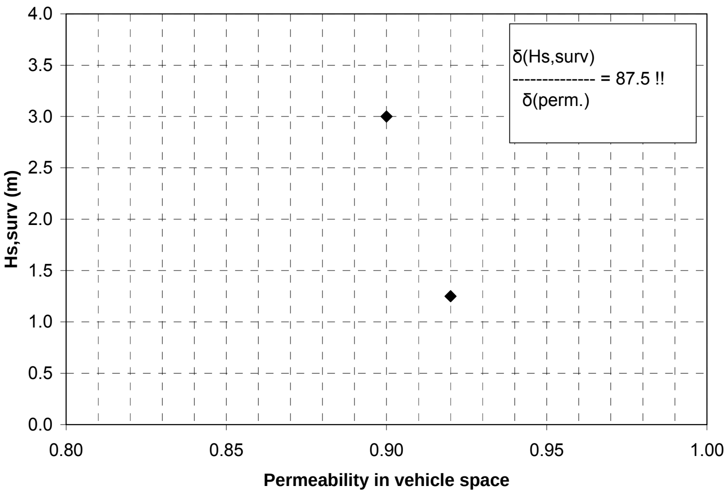


Figure 4 *The survive wave height for the damage ROPAX in variation of the permeability of the vehicle space.*

Thereof, a small change in permeability by 0.02 resulted a large increase of the survive wave height. The corresponding trend equals 87.5, which practically indicates a jump of $H_{s,surv}$ at the region of the critical permeability 0.92.

The detected jump may be analyzed on the basis of the residual stability, as commented above with Figure 2. And, it suggests the presence of a critical permeability for the survive wave height, which appears to be dominated by the stability range and less by the GZ_{max}.

Discussion

Survive events

Besides the physical definition of the capsize event, namely the turnover of the ship, in the ship stability other conventional definitions used to be applied. According to ITTC either a large heel angle of 30 deg or a long time of heeling over 20 deg are used to detect a capsize event. These criteria rather define a survive event, or a dangerous heeling and a potential capsize event.

In the herein studied case of permeability μ=0.90 and for the survive waves, the ship was heeling at an average angle between 30-35 degrees towards the damage side and then it was rolling around that heel angle, as shown in Figure 5. This mean heel angle is due to the floodwater which was accumulated on the vehicle space during a period of approximately 5 min after the collision damage.

This characteristic response would be actually a non-survive event according to conventional survive criteria, because roll exceeded 30 deg. However the ship has reached a stable equilibrium below 35 deg and may survive thereafter. This roll response was systematically repeating for the tested wave heights of 3.0 m.

The estimated survive height as presented in above Figure 4 has been based on the physical survive of the vessel, instead of a conventional one. While in a context of conventional survivability the survive height $H_{s,surv}$=3.0 m for μ=0.90 would not be detected, but most likely some other height a bit higher from $H_{s,surv}$=1.25 m, which is the height for μ=0.92.

A characteristic roll response for the case μ=0.92 is shown in Figure 6, where the ship rolls around a considerably lower angle of 6 deg.

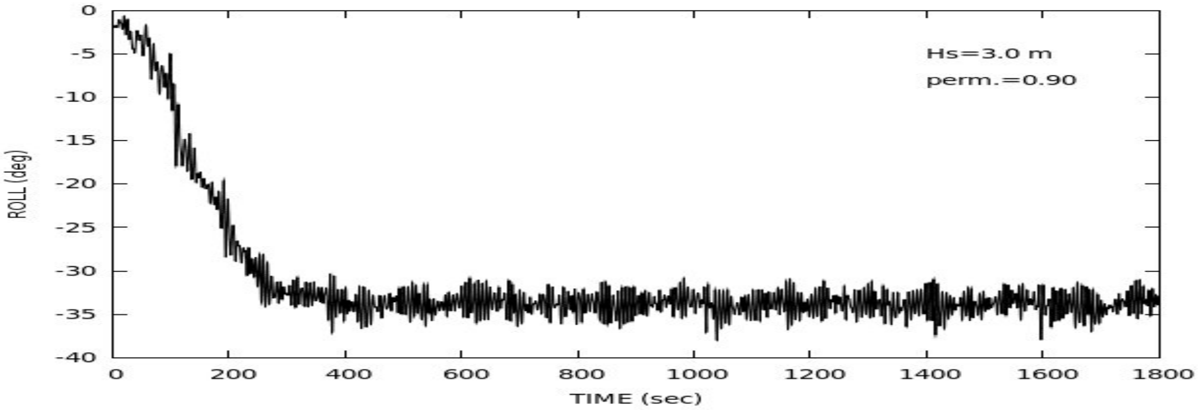


Figure 5 *Roll motion in survive test, permeability 0.90*

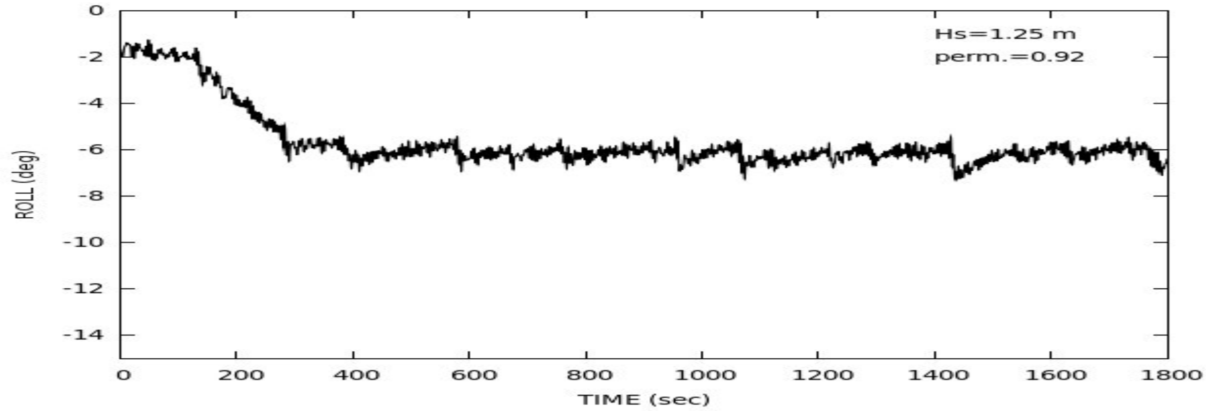


Figure 6 *Roll motion in survive test, permeability 0.92*

Permeability of the vehicle space

This study has shown that a critical permeability for the vehicle deck may appear around μ=0.92. The ROPAX vessel gets an improved physical resistance to capsize for permeability less than the critical value.

According to SOLAS (Ch.II-1, Reg.7-3.2) the permeability of the vehicle space is assumed 0.90. This value is lower the critical value of this vessel. And the corresponding 10% of buoyancy on the vehicle deck improves the physical survivability.

Reversely, if a higher permeability e.g 0.93 would be assumed then this favoring of survivability would be missing and some worse stability conditions would be defined.

Stability standard

The appearance of some critical permeability for the survivability of ROPAX ships should not be considered as an additional complication to the already intricate problem of the damage stability assessment. The permeability impact is directly reflected on the residual stability which is traditionally the main subject for the stability evaluation.

The situation would be different if the permeability affect survivability without some characteristic impact on the residual stability. In such case it would not be feasible to distinguish such gaps on the basis of residual stability.

However, the assumed permeability should be carefully considered for the development of stability standards, as it may strongly affect the survivability.

Conclusions - Suggestions

1. The permeability of the vehicle space may be critical for the survive wave height. Here a critical value of 0.92 was detected.
2. Lower permeability for the vehicle space may dramatically improve the physical survivability of the damaged ship in waves. A value of 0.90 may be already favorable to the ship survivability.
3. In a safety context, a higher permeability for the vehicle space, i.e. 0.95, would be obviously an improved stability standard.
4. The above findings should be further validated with independent studies and of course with tank tests.

References

[1]. EMSA study (2010), Study of the specific damage stability parameters of Ro-Ro passenger vessels according to SOLAS 2009 including water on deck calculation, Tender N^o EMSA/OP/08/2009.

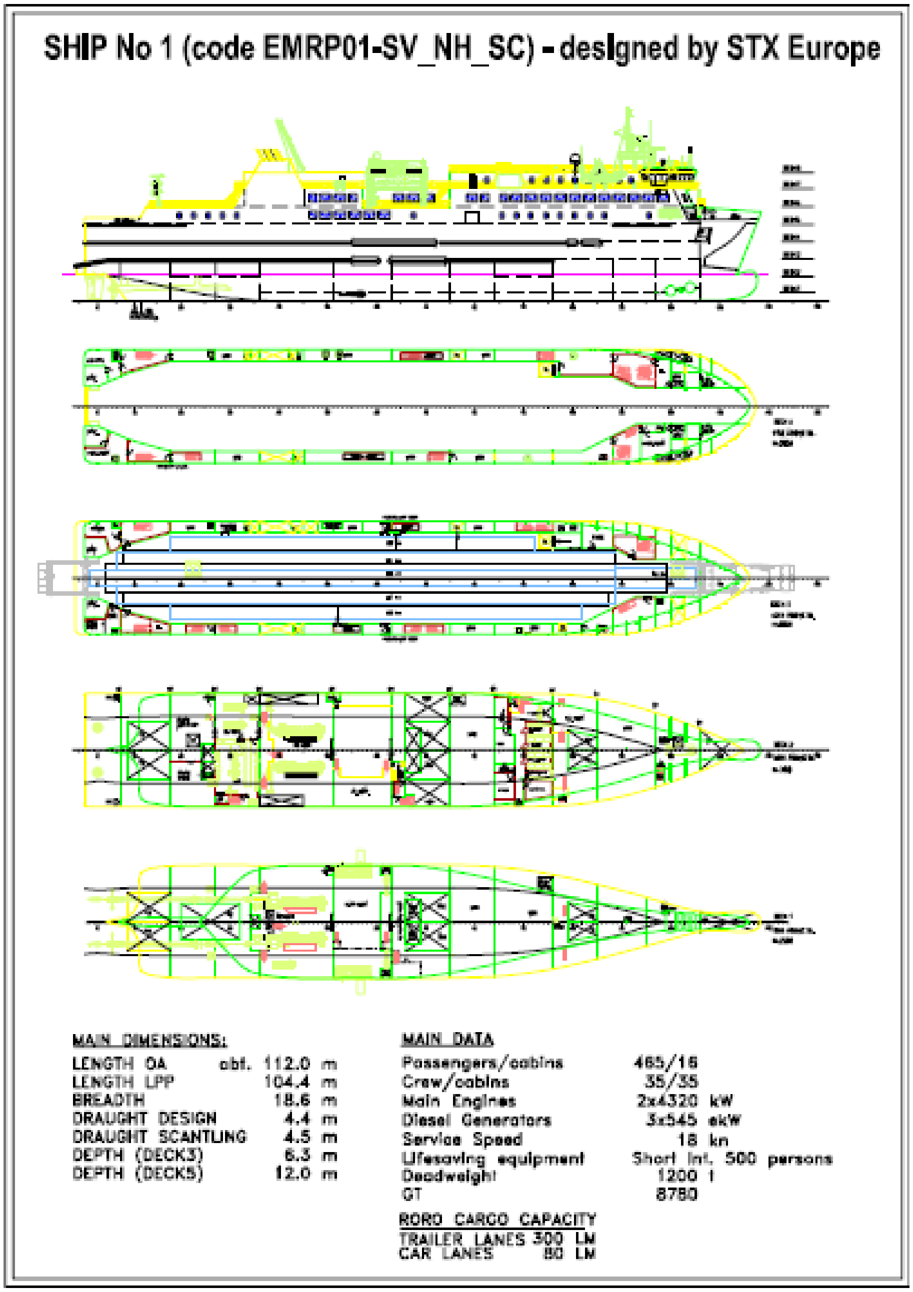
[2]. SSRC, Progress Information on ”Study of the specific damage stability parameters of Ro-Ro passenger vessels according to SOLAS 2009 including water on deck calculation”, 09-EMSA/OP/08/2009 (April 26, 2010)

[3]. Spanos, D.A., Time Domain Simulation of Motion and Flooding of Damaged Ships in Waves, Doctoral Thesis, Ship Design Lab., National Technical University of Athens, 2002.

APPENDIX – SHIP DATA

The ship data and other particulars as provided by SSRC and used for this work as summarized in this appendix.

General Plan



SHIP No 1 (code EMRP01-SV_NH_SC) - designed by STX Europe

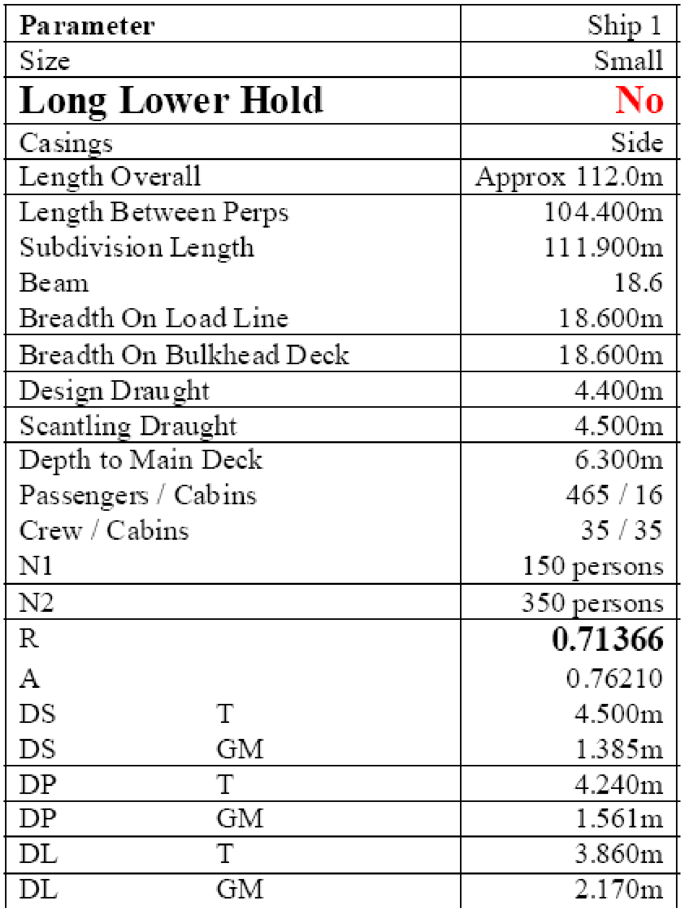
MAIN DIMENSIONS:		
LENGTH OA	abt.	112.0 m
LENGTH LPP		104.4 m
BREADTH		18.6 m
DRAUGHT DESIGN		4.4 m
DRAUGHT SCANTLING		4.5 m
DEPTH (DECK3)		6.3 m
DEPTH (DECK5)		12.0 m

MAIN DATA	
Passengers/cabins	465/16
Crew/cabins	35/35
Main Engines	2x4320 kW
Diesel Generators	3x545 ekW
Service Speed	18 kn
Lifesaving equipment	Short Int. 500 persons
Deadweight	1200 t
GT	8780

RORO CARGO CAPACITY	
TRAILER LANES	300 LM
CAR LANES	80 LM

Figure 7 *General arrangement for SHIP1 (copy from [2])*

Damage Stability Particulars



Parameter		Ship 1
Size		Small
Long Lower Hold		**No**
Casings		Side
Length Overall		Approx 112.0m
Length Between Perps		104.400m
Subdivision Length		111.900m
Beam		18.6
Breadth On Load Line		18.600m
Breadth On Bulkhead Deck		18.600m
Design Draught		4.400m
Scantling Draught		4.500m
Depth to Main Deck		6.300m
Passengers / Cabins		465 / 16
Crew / Cabins		35 / 35
N1		150 persons
N2		350 persons
R		**0.71366**
A		0.76210
DS	T	4.500m
DS	GM	1.385m
DP	T	4.240m
DP	GM	1.561m
DL	T	3.860m
DL	GM	2.170m

Figure 8 *Damage stability parameters (copy from [2])*

Damage Case

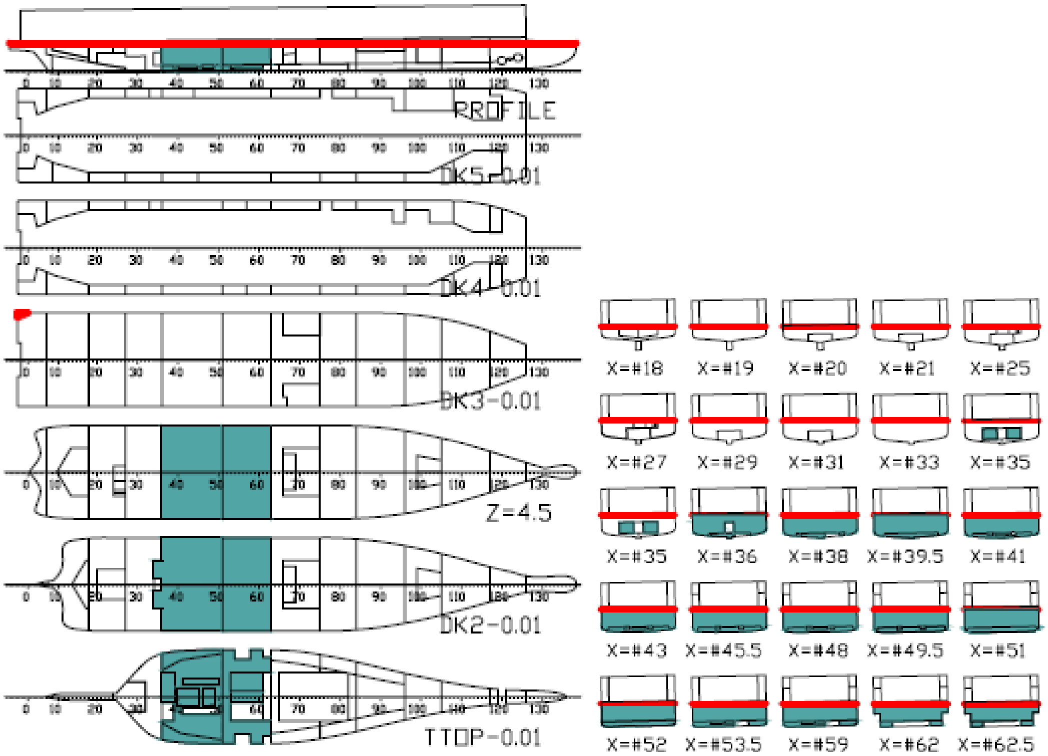


Figure 9 *Damage case DS/R7_P6-7.4.0 (copy from [2])*

Damage Opening

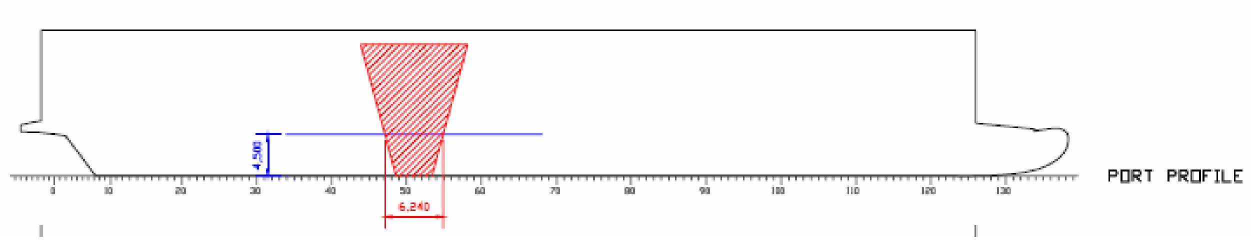


Figure 10 *Damage opening like in model tests (copy from [2])*

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Located on bulkhead between the two damaged compartments
Ld    6.240 m  (= 3%L+3, L=108m)
Bd    3.720 m  (=B/5)
Triangular penetration, unlimited height, 30 deg V-shape
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Ship Loading condition

Intact Ship

T	4.50 m	
Displ.	5500 tn	
KG	8.892 m	(GM=1.385 m)
Trim	0.0 m	

Other Assumed Data

i_{xx}	7.44 m	(= 0.40B)
i_{yy}	26.1 m	(= 0.25L)

Other Particulars

Double bottom height	1.30 m	(from drawings)
Frame spacing	0.60 m	from aft end to fr.12
	0.80 m	from fr.12 to fore end
Aft end of DWL	-1.86 m	
Fore end of DWL	108.21 m	