GOALDS – Goal Based Damage Stability

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ABSTRACT

The new probabilistic damaged stability regulations for dry cargo and passenger ships (SOLAS 2009), which entered into force on January 1, 2009, represent a major step forward in achieving an improved safety standard through the rationalization and harmonization of damaged stability requirements. There are, however, serious concerns regarding the adopted formulation for the calculation of the survival probability of passenger ships, particularly for ROPAX and large cruise vessels; thus eventually of the Attained and Required Subdivision Indices for passenger ships. Furthermore, present damaged stability regulations account only for collision damages, de-spite the fact that accidents statistics, particularly of passenger ships, indicate the profound importance of grounding accidents. The present paper outlines the objectives, the methodology of work and early results of the EU funded, FP7 project GOALDS (Goal Based Damaged Stability, 2009-2012), which aims at ad-dressing the above shortcomings by state of the art scientific methods and formulating a rational regulatory framework, properly accounting for the for the damage stability properties of passenger ships.

KEYWORDS

Damage ship stability; probabilistic assessment, goal-based design; risk-based design; passenger ship safety.

A	Attained Subdivision Index
CDF	Cumulative Distribution Function
PDF	Probability Density Function
LRF	Lloyd's Register Fairplay
TTS	Time To Sink

1. INTRODUCTION

In January 2009, the new harmonized probabilistic rules for ship subdivision became mandatory, initiating a new era in rule-making in the maritime industry in line with contemporary developments, understanding and expectations. This was the culmination of more than 50 years of work, one of the longest gestation periods of any other safety regulation. Considering that this is indeed, a step change in the way safety is being addressed and regulated, "taking our time" is well justified (Papanikolaou, 2007).

One of the great achievements of this effort was thought to be the harmonization of standards for dry cargo and passenger vessels in a probabilistic frame-work which allows for a rational assessment of safety and design innovation. In this state of affairs, the EU-funded R&D project HARDER (1999-2003), created history at IMO by being the first externally funded research project to support specifically the IMO rule making process and to contribute massively to the successful development of the new rules.

However, with a number of ship owners opting to follow these new rules in advance and as of today, a number of issues were surfacing, which require urgent consideration, as these affect the most safety-critical ships, namely large passenger ships, which are currently one of the fastest growing ship sectors and what is more important these ships constitute the core strength of the European shipbuilding industry. Also, great concerns were expressed by EU member states and the European Maritime Safety Agency (EMSA) regarding the abolishment of the Stockholm Agreement provisions for ROPAX ships, when the new SOLAS 2009 entered in to force; in fact, there was strong evidence that SOLAS 2009 does not satisfactorily cover Water On Deck effects on ROPAX survivability (e.g., HSVA, 2009). These concerns, which form the kernel of the rationale for the research reported in this paper, can be summarized as follows:

- As the required subdivision index was derived by harmonization (based on existing vessels, built in the 90ties), the new damage stability standard being statistical in nature (rather than performance-based) could not implicitly cater for the higher level of safety inherent (required) in mega-passenger ships; it rather maintains a safety level fit for the ships of a bygone era.

- In addition, lack of proper consideration (due to lack of availability) of large passenger ships in the sample studied in Project HARDER, raised concerns during the harmonization process as to the suitability for the developed standards for damage stability among the IMO delegates, leading to a strong and explicit recommendation in IMO SLF47 to undertake pertinent research to address the damage stability standards for these ships (specifically to reformulate the probability of survival in a damage condition – s factor).

- In addition, only survivability following *collision events* was addressed. A similar formulation for *grounding accidents* was not developed.

- Within the EU-funded R&D project SAFEDOR (2005-2009), a series of high-level formal safety assessments (FSA studies) were performed for cargo and passenger vessels. The FSA studies on cruise and ROPAX vessels both concluded that the risk to human life could be reduced cost-effectively by increasing the required subdivision index.

- The results of the FSA on cruise vessels performed within SAFEDOR show that a reduction of risk by 2.1 lives per ship per lifetime (30 years) may be achieved by increasing either GM or freeboard. Both design measures are shown to be cost-effective according to IMO criteria. However, due to the high-level approach within a FSA, only generic design measures were explored and found to be cost-effective. No complete new concept ship design was created to check the consequences of introducing higher subdivision requirements. Therefore, the FSA studies recommend undertaking research to investigate more thoroughly this issue.

- Recent experience in the design of new large passenger ships according to the forthcoming probabilistic rules, tend to emphatically reinforce the foregoing. The rules appear to be inconsistent with design experience for high survivability for these ships and the level of vessel achieved in some of these designs is far higher than the level demanded by the rules, suggesting that there is “room” for higher standard of safety for large passenger ships without penalizing other design considerations; this is in full support of the FSA findings.

- Developing SOLAS 2009 as a new damage stability global standard, the consideration of Water On Deck effects on the survivability of ROPAX vessels was not an issue, as this was covered by the Stockholm Regional Agreement; thus, inherently, SOLAS 2009 could never be an equivalent for SOLAS 90 + Stockholm Agreement provisions.

- Developments within SAFEDOR of holistic approaches in dealing with ship safety have revealed that the risk to human life from flooding (resulting from collision and grounding accidents) dominates the safety of passenger ships (almost 90% of the total risk), thus making it imperative to "get damage stability right" (see, Vassalos D. in Papanikolaou (ed), 2009).

- Other developments within IMO concerning the safety of large passenger ships, led to concepts of progressively more holistic nature, namely "Safe Return to Port", again with flooding (and fire) accidents at the very centre of such developments; this necessitating a more thorough understanding of how damage stability ought to be catered for in ship design and operation.
- Along similar lines, one of the top-agenda items at IMO, namely Goal-Based Standards is targeting in the longer term all ship types, with of course passenger ships being a main target, implicitly again pointing towards the need to sort out the damage stability standard for large passenger ships.

This latter point provided the inspiration for the title of the present research project, namely "Goal-Based Damage Stability" – GOALDS; it aims to contribute to IMO regulatory work in a similar fashion to HARDER supported by a consortium of partners that essentially comprises the same core partnership.

The project addresses the above outlined challenges by undertaking research to improve the current survivability formulation, to integrate collision and grounding damage events, to proceed to a risk-based derivation of a new subdivision requirement and conduct a series of concept design studies to ensure the practicability of the new formulation. Upon completion, GOALDS will submit key results to IMO for consideration in the rule making process. More specifically, GOALDS key objectives are to:

- Develop an enhanced formulation for the survival factor "s" accounting for key design parameters of passenger ships and for the time evolution of flooding scenarios; it evident that the formulation of the new survival factor will cater for the design differences between cruise and ROPAX ships.
- Develop a new survivability formulation for flooding following grounding accidents.
- Integrate collision and grounding survivability formulations into a single framework
- Validate the new formulations by experimental and numerical analyses
- Develop a new damage survivability requirement in a risk-based context
- Evaluate the practicability of the new formulations by a series of ship concept design studies
- Upon completion, submit results for consideration by IMO

The project consortium consists of eighteen (18) European organizations[1], representing all major stakeholders of the European maritime industry (yards, class societies, operators and flag states), research institutes and universities. Practically all project partners and in particular the major drivers of the project collaborated successfully in the past in the completion of the related projects SAFER-EURORO, HARDER and SAFEDOR. Also, an Advisory Committee has been formed composed of representatives of major public regulatory authorities and CESA, to the extent they are not already active partners in the project. The AC is meant as a sounding body for the consortium as well as a platform for early discussion of project results related to the

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[1] National Technical University of Athens-Ship Design Laboratory (coordinator), Universities of Glasgow and Strathclyde-Ship Stability Research Centre, Germanischer Lloyd, Det Norske Veritas, Safety at Sea, Lloyds Register, Hamburg Ship Model Basin, Vienna Model Basin, Danish Maritime Authority, Maritime and Coastguard Agency, University of Trieste, STX Europe-France, STX Europe-Finland, FINCANTIERI, MEYER Werft, Color Line, Carnival PLC, Royal Cruises Lines, http://www.goalds.org.

preparation and consolidation of regulatory proposals to IMO[2] .

2. OBJECTIVES & EARLY RESULTS[3]

The project's detailed objectives and work plan may be found in the public domain area of the project's web site http://www.golds.org. In the following, some early scientific results of the project are presented.

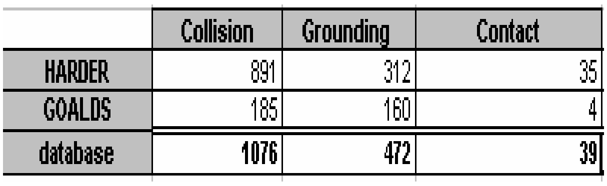
2.1 Damage Statistics for Collision and Grounding

Some early work of the project is focusing on an update of the collision damage statistics compiled in the HARDER project; these statistical data were also subsequently updated by a number of flag state delegations as part of the rule making process at IMO; the aim of GOALDS is herein to collect and analyse latest damage data, available to the project, and to provide suitable probability distributions for collision damage characteristics pertinent to passenger ships. To this end the GOALDS database builds on the existing HARDER database, with additional data coming from all stakeholders participating in the project, as well as from other publicly available accident databases.

Whereas the earlier damage statistics were limited to collision damages only, in the present project we consider also grounding damages; this work was actually initiated but was never completed within the project HARDER. In this respect, emphasis will now be placed on the grounding damage characteristics of passenger ships, noting that grounding is a very serious hazard for passenger ships' survivability.

The HARDER database includes casualties from 1944 up to the year 2000. To identify the casualties in the last 10 years, the Lloyd's Register Fairplay database (LRF) has been used, whereas the characteristics of these damages were deduced mainly from class societies' records. A total number of 1587 casualties could be recorded in the updated database (349 GOALDS, 1238 HARDER). It was differentiated between collision, grounding and contact damages, as shown in below table (Table 1).

Table 1: Collected damage data by hazard and origin for the period 1944 to 2010



	Collision	Grounding	Contact
HARDER	891	312	35
GOALDS	185	160	4
database	1076	472	39

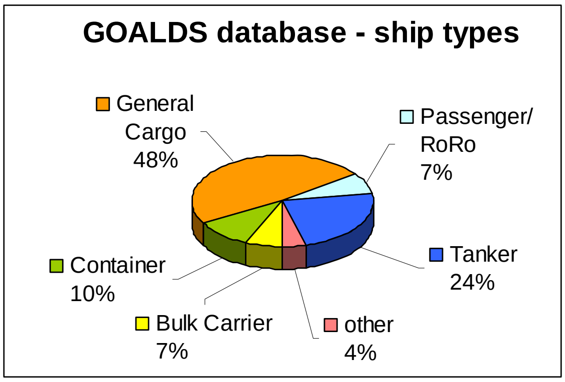


Fig. 1: GOALDS database of damage statistics – Origin of damages by ship type

The distribution of the ship types captured in the GOALDS database can be seen in the pie chart (Fig. 1).

The limited number of available damage data for passenger ships led to the conclusion that all damage data independently of ship type and time period should be considered; this was done likewise in previous relevant analyses (e.g., HARDER project). Some preliminary results of the data analysis are shown in the following graphs.

Collision:

A-1.1 non-dimensional damage position in longitudinal direction (f(x)=PDF; Nx=Number of casualties)

A-1.2 non-dimensional damage length f(x) = PDF, F(x) = CDF

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[2] Association of European Shipbuilders CESA, flag states: Maritime Administrations of Norway, Sweden, Netherlands, Finland, Germany and USA, noting that the Maritime Administrations of Denmark and United Kingdom are already regular members of the consortium.

[3] At the time of preparing this paper, the project was practically 6 months underway, thus only some early results are herein presented.

Grounding:

A-1.1 nondimensional damage position in longitudinal direction (f(x)=PDF; Nx=Number of casualties)

A-1.2 nondimensional damage length f(x)= PDF, F(x) = CDF

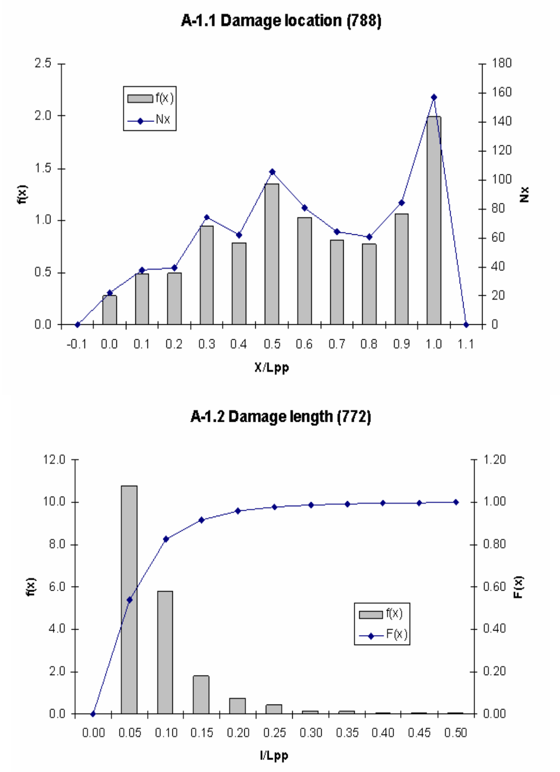
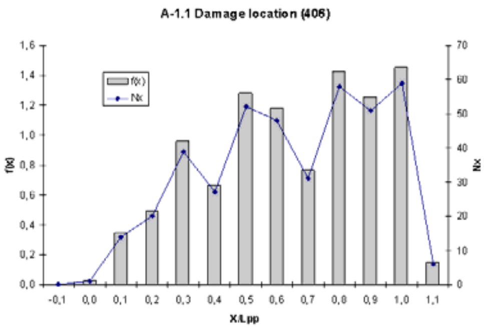


Fig. 2: Damage location and length for collision damages according to GOALDS database



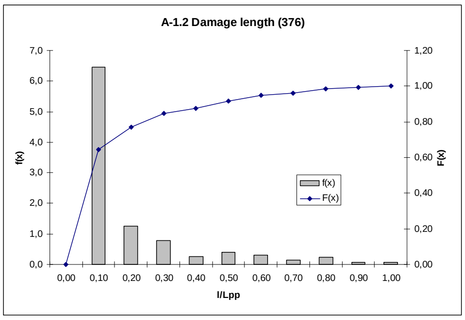


Fig. 3: Damage location and length[4] for grounding damages according to GOALDS database

2.2 Numerical Studies on Survivability Benchmarking of Numerical Codes

Project GOALDS has introduced a new era in damage survivability research. For the first time ever, numerical simulations will be utilised to produce the bulk of results, which will then be used for the development of the new s factor formulation, following validation through physical experiments. This is a sign of the confidence that the research community has gradually acquired in relevant simulation codes that pave arguably the way forward. Most of the partners involved in this project have long experience or are presently in the process of developing their own damage stability simulation codes. Thus, it is sensible to share the effort between those involved, firstly for efficiency and secondly for verification purposes.

However, before distributing project's simulation effort to qualified project partners, a benchmarking of the employed numerical codes would be necessary. This is actually a verification of the outcome of earlier related damage stability benchmarks of codes, organised by ITTC and SAFEDOR (see, Papanikolaou, 2007). To this end, the ROPAX ship PRR-1, which has been used in a number of previous studies, was selected for benchmarking. Results for PRR-1 from

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[4] Regarding the recorded damage length of groundings, special attention was paid to the consideration of multiple holes' damages by an equivalent damage length

physical testing already exist from the HARDER project, a fact that makes this particular ship a good base for benchmarking studies. In addition to this, it is a typical example of a middle-sized ROPAX vessel, without the controversial feature of a long-lower hold.

Table 2: PRR-1 main particulars

Length over all	194.30	m
Length between perpendiculars	170.00	m
Subdivision Length	178.75	m
Breadth	27.80	m
Depth to subdivision deck (G-Deck)	9.00	m
Depth to E-Deck	14.85	m
Keel thickness	14.85	m
Service Draught	6.25	m
Displacement	17301.7	ton
KMT	15.522	m
KG	12.892	m
VCG	3.595	m
LCB	81.891	m

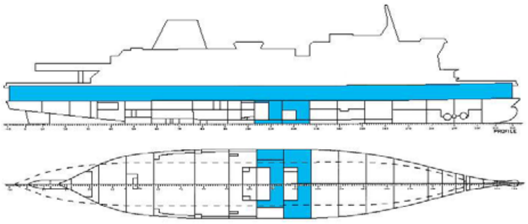


Fig. 4: **PRR-1 and Test Damage**

Obtained numerical results by two project partners (NTUA-SDL & SSRC) show reasonable convergence with respect to comparable experimental results, as well as among themselves. Static stability calculations seem to be in perfect match between the two simulation contributors so far (P1 & P2) as shown in Figs 5~6. Concerning the dynamic damage stability simulation results, both codes under-predict to a certain degree survivability, compared to available experimental results; this is less worrying as it places numerical results on the safe side, Fig. 7. Thus and pending verification by further benchmarks, numerical predictions appear to lead, in general, to conservative survival predictions.

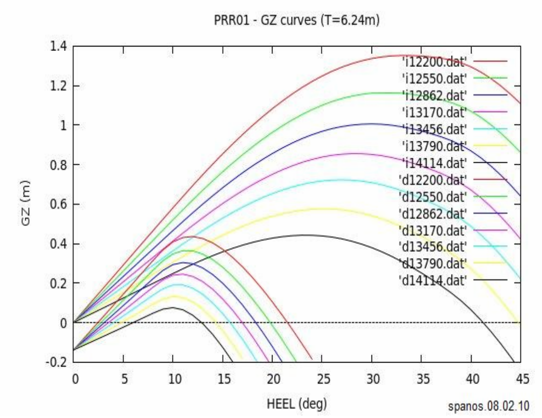


Fig. 5: PRR01-GZ curves calculated by P1 code

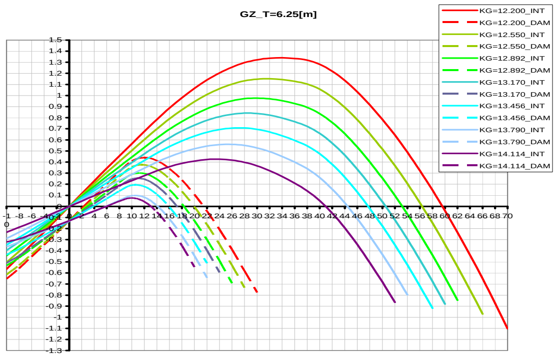


Fig. 6: PRR1-GZ curves calculated by P2 code

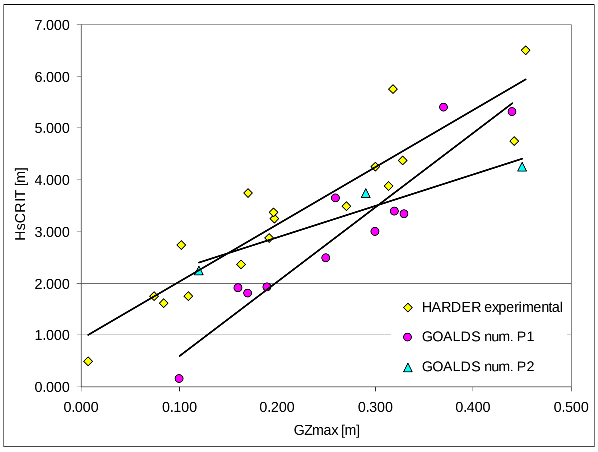


Fig. 7: **Experimental vs. numerically simulated results by codes P1 and P2**

Table 3: PRR-1 Tests

Model tests						Simulations (P1, P2)			
Init T	Init tr	KG	GZ_{MAX}	Range	Hs_{CRIT}	Init tr	KG	GZ_{MAX}	Hs_{CRIT}
[m]	[deg]	[m]	[m]	[deg]	[m]	[deg]	[m]	[m]	[m]
6.25	0	12.200	0.442	20.200	4.750	0	12.200	0.44	5.32
6.25	0	12.892	0.300	15.900	4.250	0	12.550	0.37	5.40
6.25	0	13.456	0.192	12.200	2.875	0	12.750	0.33	3.34
6.25	0	14.114	0.074	7.100	1.750	0	12.892	0.30	3.00
6.25	-1	12.200	0.314	16.600	3.875	0	13.170	0.25	2.48
6.25	-1	12.892	0.197	12.474	3.250	0	13.456	0.19	1.92
6.25	-1	13.456	0.109	9.000	1.750	0	13.790	0.10	0.16
6.25	1	12.200	0.328	18.800	4.375	***0***	***12.000***	***0.45***	***4.25***
6.25	1	12.892	0.196	13.930	3.375	***0***	***13.000***	***0.29***	***3.75***
6.25	1	13.456	0.102	9.800	2.750	***0***	***14.000***	***0.12***	***2.25***
6.25	1	14.114	0.007	2.400	0.500				
5.75	0	12.892	0.453	21.400	6.500	0	13.456	0.32	3.39
5.75	0	13.458	0.318	17.600	5.750	0	14.114	0.17	1.80
5.75	0	14.114	0.170	12.560	3.750				
6.75	0	12.200	0.271	14.000	3.500	0	12.200	0.26	3.65
6.75	0	12.892	0.163	12.150	2.375	0	12.892	0.16	1.90
6.75	0	13.456	0.084	6.800	1.625				

Capsize Band

Probably more important than the critical (survival) wave height per se, the search for the critical seastate has revealed something new about the nature of the capsize process. As is usually the case with boundary (extreme Limits) phenomena, ship survival is not a well-defined process. It appears that there is a band within which the transition from “safe” to “unsafe” takes place. This has been conventionally named “capsize band”. This band begins at the wave height where no capsizes are observed at all (given certain uncertainty levels) and finishes at that wave height where all realisations result in loss. In order to better describe the capsize band, another term has been introduced, the “rate of capsize” (PF). This is no more than the probability of capsize, given a seastate. So PF will be 0 at the lower end of the capsize band and 1 at the upper end. The point of the capsize band where PF = 0.5 is the critical wave height (Hs_{crit}) and it is this value that is used by convention when referring to ship survivability.

The capsize boundaries are symmetrical, either side of the Hs_{crit}, whilst the capsize band follows a specific pattern. Applying non-linear regression to the results from the simulations it seems that there is a perfect fit for a *sigmoid* distribution (Fig. 8).

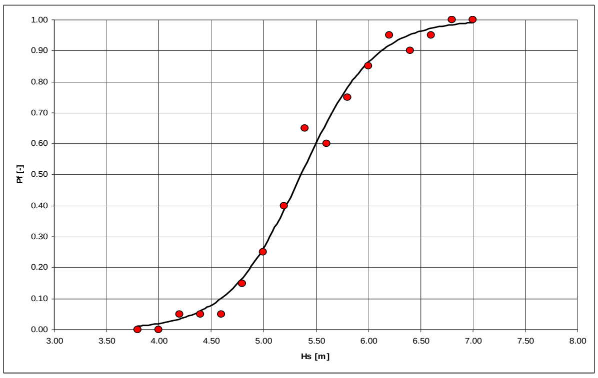


Fig. 8: Capsize band and fitted sigmoid

Another attribute of the capsize band is that it is varying with critical wave height. More specifically, the higher the critical wave height, the broader the bandwidth and visa versa. This is visible in Fig. 9, where the capsize band has been established for various conditions for PRR-1. Appropriate curves have been fitted to make results clearer.

The fitted sigmoid curves are described by four parameters: A0, A1, x0, dx that are lower P_F (=0), upper P_F (=1), critical wave height and bandwidth respectively. With A0 and A1 being predefined it is rather easy, having just two parameters, to express capsize band analytically. The solution put forward shall be based on those properties of the fitted curves, as well as characteristics of the ship geometry and loading condition.

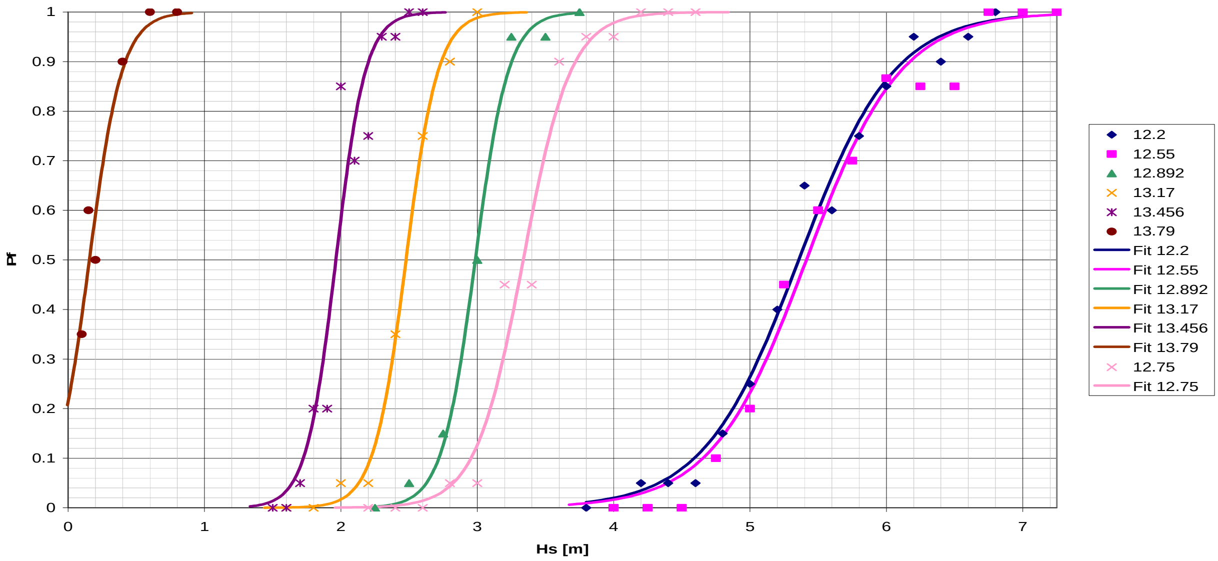


Fig. 9: Variation of the capsize band for various critical wave heights

2.3 Experimental Studies on Survivability

One the main project’s objectives is to provide experimental evidence on the process of ship stability deterioration after hull breach, typical for collision and grounding accidents. The evidence corresponds to the relation between specific set of damage and environmental conditions and the corresponding time it takes for the limit state condition to evolve (vessel losing its functional equilibrium attitude). Results will be used for the verification of related numerical predictions of the survival factor (s-factor), as outlined in the previous section.

The experiments will be undertaken for two representative large ROPAX and two Cruise Liner ships. Two model basins will conduct the model experiments, namely Vienna Model basin will build and carry out experiments for cruise vessels and HSVA (Hamburg) will be in charge of the ROPAX vessels. The main data of the sample vessels selected for the physical experiments are given in the following table (Table 4).

Table 4: Main data of GOALDS test ships

Ship	Ropax (R1)	Ropax (R2)	Cruise ship (C1)	Cruise ship (C2)
Number of passengers	1400	622	3840	2500
LOA	194.3 m	97.9 m	311.123 m	294.81 m
LBP	176.0 m	89.0 m	274.73 m	260.6 m
Breadth moulded	25.0 m	16.4 m	38.6 m	32.2 m
Deepest subdivision loadline	6.55 m	4.0 m	8.6 m	8.0 m
Depth to bulkhead deck	9.1 m	6.3 m	11.7 m	10.6 m
Displacement	16,558 tn	3,445 tn	62,459 tn	45,025 tn
Service speed	27.5 kn	19.5 kn	22.6 kn	22.0 kn

All sample vessels, the data of which were supplied by project partners, are ships designed in compliance with the deterministic SOLAS ’90 damage stability regulations. The decision to select SOLAS 90 ships as a baseline for the development of the GOALDS damage stability standard was made after thorough discussions among the project partners; this, namely, ensured, a common baseline with comparable numerical and experimental data obtained in the HARDER project, whereas the harmonized probabilistic SOLAS 2009 was also developed on an equivalent basis with SOLAS 90.

Damage Selection

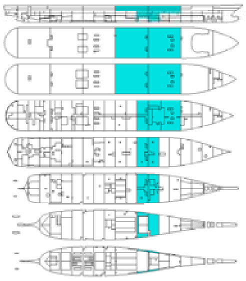
The selection of the damage location and extent for the model experiments is straightforward for the collision damages, in view of past experience with respect to the identification of worst damage; however, it is less clear with the groundings, for which less experience exists. Thus, the location of the grounding damages for the selected sample ships was specified on the basis of the statistical data collected by the project; for the critical grounding, it was assumed that 4 compartments of the double bottom will be flooded, with the additional penetration of the centre watertight bulkhead above the inner bottom to allow for up-flooding.

The location of the collision damage was derived using “worst SOLAS damage (2-compartment damage up to B/5, ±35%L from amidships)” with regard to the minimum area under the residual positive GZ curve; this was cross checked with results of numerical simulations of same damages. Numerical simulations accounting for dynamic effects contributed to identifying additional damages, which would affect capsize and/or cause extreme roll motions.

The impact of the various explored damages was assessed by application of both SOLAS 90 provisions and numerical simulations; the results were graded with respect to their severity; for each vessel a comparative grading table was prepared, ranking the severity of the various damages (Table 5). The least sum resulting from the ranking of the severity according to both methods indicates the damage selected for experiments. It should be noted that in case of test cruise vessels, a *3-compartment damage* of outer shell will be used in order to approach the survivability boundary. In general it was agreed that for verification purposes suitable statistical damages beyond SOLAS 90 standard (i.e. increased penetration) will be included in the tests, to ensure that the formulation of the s factor will capture realistically the physics of related damages.

After the test damages were selected the corresponding model drawings were prepared and a test matrix for each vessel type was established. The first two vessels to be tested in summer 2010 are C1 and R2.

Table 5: Ranking of damage cases according to severity



Case	SOLAS '90	Simulations	Sum	35%
1-2	18	-	-	
2-3	16	1	17	
3-4	6	2	8	
4-5	14	15	29	Y
5-6	12	16	28	Y
6-7	8	3	11	Y
7-8	11	4	15	Y
8-9	9	14	23	Y
9-10	7	10	17	Y
10-11	10	13	23	Y
11-12	5	8	13	Y
12-13	13	5	18	Y
13-14	1	6	7	Y
14-15	3	9	12	Y
15-16	2	7	9	Y
16-17	4	11	15	Y
17-18	15	12	27	Y
18-19	17	17	34	
19-20	19	18	37	
20-21	20	-	-	

Table 6: Typical sample ship test matrix

		Irregular waves JONSWAP 1/25			
		H_1	H_2	...	$H_{max = 4.0m}$
Loading conditions	DL (1m trim)	(x)	(x)	...	(x)
	DP (0 trim)	x	x	...	X
	DS (0 trim)	x	x	...	x
Damage location	Col 1	x	x	...	x
	Col 2	-	-		-
	Grounding	x	x	...	x
Damage extent	2-comp*	x	x	...	x
	3-comp**	x	x	...	x
Penetration	Shell	x	x	...	x
	B/5	-	-		-
Centre of Gravity	KG1	x	x	...	x
	KG2	x	x	...	x
	KG3	x	x	...	x
Transient	In waves	(x)	(x)	...	(x)
	Calm water	x			

A typical Test Matrix (Table 6) includes testing of one collision and one grounding damage for each ship and for 3 draughts (DS, DP and DL), initially with maximum KG values (SOLAS 90); subsequently, the KG values will be increased in an attempt to capture the survivability boundary. Also, the significant wave height will be gradually increased to a maximum of Hs=4.0m.

2.4 Risk-based Damage Stability Requirement

A complete risk model considering both collision and grounding will need the following elements to be in place:

1. Collision and grounding frequency, i.e. how often a collision and grounding takes place.
2. Flooding frequency, i.e. how many of the collision or grounding cases actually lead to flooding.
3. Probability of not surviving the collision or grounding given flooding. This is ideally equal to 1-A, where A is the attained index according to the probabilistic rules.
4. Giving non-survival, how much time is available to evacuation.
5. Given the estimated time, what is the likely outcome of the evacuation?

This may be illustrated as follows, Fig. 10:

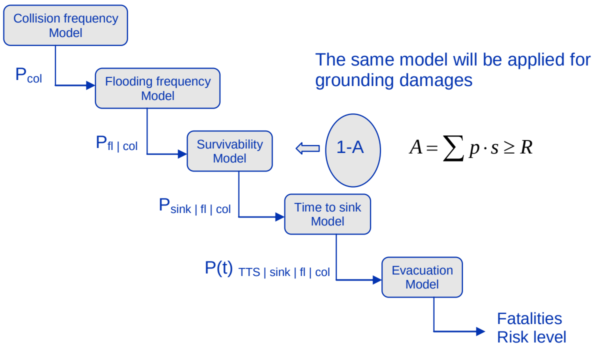


Fig. 10: Model of risk-based damage stability requirement

Some background information about the formulation of the risk-based damage stability requirement of GOALDS may be found in Skjong et al., 2006.

2.5 Innovative ship concept designs based on the new damage stability requirement

In order to investigate the impact of the new formulation for the probabilistic damage stability evaluation of passenger ships on the design and operational characteristics of characteristic ROPAX and cruise vessels, it is planned to conceptually design and optimise innovative vessel layouts, meeting the new damage stability standard, while considering building cost and efficiency in operation.

An existing integrated design optimisation procedure (Zaraphonitis et al., 2003) of NTUA, encompassing the parametric design and optimization of ROPAX vessels, will be extended to account for cruise ship design layouts and adapted to the new damage stability standard. Participating industry will be providing expertise and empirical data, as necessary for the implementation of the developed procedure.

The resulting design concepts will be further elaborated to the preliminary stage by the participating shipyards, namely Fincantieri, Meyer Werft, STX Finland and STX France.

3. SUMMARY AND EXPECTED OUTCOME

This paper presented the objectives and reviewed early results of the EU funded, FP7 project GOALDS. The main expected outcome of GOALDS is its contribution to enhanced safety of the passenger maritime transport and the facilitation of the application of rational, risk-based procedures to the design of ROPAX and cruise ships, a clear domain of the European shipbuilding industry. This will be achieved by delivering a rational, fully validated, robust and consistent method for assessing the safety of passenger ships in case of a collision or grounding. In this way, the project aims at further developing and complementing past work of the successful HARDER project, which decisively contributed to the development and the adoption of the new harmonized damage stability regulations pertaining to all types of dry cargo and passenger ships. This project outcome is being sought not only by the European maritime community, but the entire international maritime community has been working in recent years on the further improvement of passenger ship’s safety, especially in view of ultra large cruise ship designs and operations.

On the way to this goal, the project will deliver a whole array of useful applications and products. The project will provide a quantum leap in understanding the complex physics behind the behaviour of a damaged passenger ship, considering the fundamental differences in ROPAX and cruise ship design, and the unique concept of simplified generic models should enable designers and regulators with far better tools than before for making rational designs and regulations. New and updated damaged databases will be established, and unique tools for quantifying the probability of damage and calculating expected extent of damage following a collision or grounding will be exploitable by all parties.

The results are mainly targeted to assist regulators in their work with new and improved regulations for passenger ships covered by SOLAS, with an expected time for exploitation of maximum three years. The timing is very appropriate in light of the need for new passenger ships to comply with expected growth of the water-borne transportation in Europe and the international cruise business. By introduction of new and rational, risk-based criteria now, new passenger ships may be designed with greater flexibility without compromising safety.

The main product of GOALDS – a rational probabilistic approach to assessing collision and grounding of passenger ships and the rational criteria deriving there from - as well as the consequence analysis tools - may of course be exploited by the maritime community on a worldwide basis, but the detailed knowledge and understanding of the method remains within Europe, and thus providing the European maritime community with a significant technological edge. This is especially valid for the shipbuilding industry, which will gain significant knowledge on how to apply the new approach on design of passenger ships following an improved probabilistic concept, better accounting for the special design features of ROPAX and cruise ships.

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