Holistic Perspective on Damage Stability Standards for RoPax Ships

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ABSTRACT

The present paper is intended to outline in brief the work and findings of a Triple-Helix project as initiated by the Swedish Shipowners' Association and concluded in mid-2015. The aim of the study has been to, in light of the ongoing IMO deliberations on revision of SOLAS Chapter II-1, review and evaluate from a holistic perspective, existing as well as proposed amendments to ro-ro passenger ship safety regulations.

Keywords: *Ro-ro passenger ship, damage stability, safety standards, holistic perspective*

1. INTRODUCTION

Ro-ro passenger ship services constitute an important part of the European maritime infrastructure, and indeed play a crucial role for Sweden in connecting seaborne transport routes to and from our neighbouring countries. Moreover, northern European countries have been leading the development of, not only the ro-ro passenger ship concept as such, but also the development of relevant safety standards for this fleet. Understandably, it is therefore crucial for the Swedish maritime sector to take part of the legislative process that covers a significant share of the Swedish maritime infrastructure.

Thus, in light of the ongoing IMO deliberations on revision of SOLAS Chapter II-1 in general and present discussions and proposals for an increased safety standard for passenger ships in particular, a Triple-Helix project has been mobilized by the Swedish Shipowners' Association, focusing on ro-ro passenger ship safety from a holistic perspective.

The aim of the study has been to review and evaluate, from holistic perspective, existing as well as proposed amendments to ro-ro passenger ship safety regulations, with the objectives to:

1. provide in-depth knowledge about and facilitate understanding of existing as well as new proposals for damage stability standards,
2. facilitate understanding of ship type specific characteristics from a safety standard aspect, and
3. if findings allow, develop comprehensive proposals for improvements resulting in a tangible safety enhancement for this ship type.

The present paper is intended to outline in brief the work and findings of the first part of this project as concluded mid-2015 [1]. Funding for a second round has recently been granted.

2. STATE OF PLAY

2.1 Background

As per the entry into force of SOLAS 2009 comprehensive amendments to SOLAS Chapter II-1 related to subdivision and damage stability requirements were introduced. Previous prescriptive concepts such as margin line, floodable length and B/5-subdivision were omitted and replaced by a probability distribution function, p_i, for a certain damage extension along the ship's subdivision length. Moreover, the deterministic assessment of single compartment and group of compartments flooding was replaced by an expression of the probability of "survival", s_i, after damage.

The rationale behind the probabilistic damage stability doctrine as applied within present SOLAS regulations, normally referred to as SOLAS 2009, is in principle based upon the assumption that the survivability of a passenger ship, defined as 50% probability to withstand capsize for more than 30 minutes following a collision damage in a seaway signified by a critical wave height of H_{Scrit}, can be expressed as a function of the maximum value of the righting lever, GZ_{Max}, and the range of positive stability, GZ_{Range}. A limiting wave height of 4.0m has been derived by means of statistics of prevailing conditions at reported collision damages. Thus, s_i = 1.0 means, in principle, a 50% probability to survive (withstand capsize) the collision damage under consideration for a time period exceeding 30 minutes in a sea state H_S = 4.0m.

Ro-ro passenger ships are conceptually different from other types of passenger ships. In addition to passenger accommodation and recreational areas, nowadays located above the bulkhead deck, this ship type is characterised by large vehicle decks designed for the carriage of rolling cargo which impose an increased risk, should water ingress occur resulting in large free surfaces on these decks. A number of devastating accidents related to this increased risk have occurred, the outcome of which must be regarded as intolerable.

Consequently, over the years and in particular post-ESTONIA northern European maritime administrations, ship owners and ship builders have actively participated in the development of new regulations, such as the so called Stockholm Agreement (SA), aiming at controlling and mitigating the added risk stemming from the conceptual nature of these ship types. The Stockholm Agreement requirements were initially implemented regionally as a practical instrument to attain an improved level of safety in respect of the specific characteristics of the ro-ro passenger ship concept. As of October 1st 2015 the SA requirements are mandatory for all ro-ro passenger ships trading between EU ports, [2], [3].

As per today ro-ro passenger ships are subject to some 20 ship type specific requirements, including design and operational aspects as well as annual Host State Control surveys for ships trafficking in European trades. In addition hereto, it is normal practice amongst at least northern European ship owners to continuously work with safety related issues, in many cases beyond legislation.

Only a few ro-ro passenger ships currently in operation are designed and built to the SOLAS 2009 standards. Hence, the absolute majority of the ro-ro passenger ship fleet presently serving the European waters are built to SOLAS ’90, and nowadays in compliance with the requirements of SA, a safety standard that in principle has never been deemed as insufficient. It could be mentioned that the intention of damage stability requirements as set forth in SOLAS 2009 was not to result in an enhanced safety level when compared to the previous deterministic damage stability standards, but rather to harmonize the subdivision and damage stability standards for passenger and cargo ships, and moreover to develop a modern regulatory framework that would provide an enhanced freedom for the designer to arrange the subdivision of a ship.

During the development of the probabilistic damage stability standards as outlined in SOLAS 2009 it was initially assumed that this safety standard would also accommodate for the risk of water on a vehicle deck. Nevertheless, SOLAS 2009 was questioned already before its entry into force. The criticism has primarily been related to the methodology’s ability to correctly address water on deck (WOD) when assessing damage stability for ro-ro passenger ships.

2.2 Passenger Ships in General

With reference to the outcome of several research projects, such as the EMSA 1 and 2 and the GOALDS project, the WOD-issue has been extensively debated within the IMO and in particular within SLF, the former sub-committee to MSC. When now SOLAS Chpt II-1 is again subject to revision, amendments emanating from SLF 55, [8], to the calculation procedures of the survivability factor s_i for ro-ro passenger ships have been proposed, aiming at providing an equivalent safety standard when compared to the Stockholm Agreement for damage cases involving vehicle decks.

In addition, catalysed by the Costa Concordia disaster, the debate was later extended to include also the overall “safety level” for passenger ships in general, expressed by the required subdivision index R. Thus, a third research study was initiated and funded by EMSA, the so called EMSA 3, [10], the results of which, as conveyed by the EU, [11], have constituted the basis for a proposal of the IMO MSC sub-committee SDC in terms of a new formulation of the required subdivision index R that is expected to provide an adequate raise in the "safety level" for passenger ships, [13], see Figure 1. The proposal is, at the time of writing, being discussed at the IMO MSC 96 with a view for approval at this session and adoption at MSC 97.

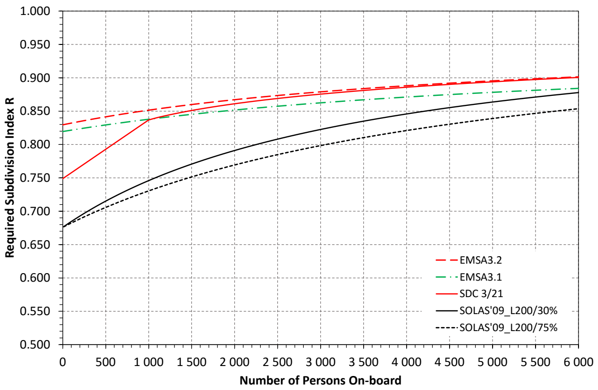

Figure 1: Graphical representation of the new formulation of Index R as proposed in SDC 3/21

The linear part of the index R line, from zero to 1 000 persons, is intended to accommodate for the fact that smaller ship were not very well represented in the EMSA 3 study. Moreover, from 1 000 to 6 000 persons on-board the proposed index R curve has been adjusted so as to fit between the EMSA 3.1 line that represents cost effective designs in respect of collision damages and the EMSA 3.2 line that represents cost effective designs in respect of both collision and grounding/raking damages.

2.3 Specific Requirements for RoPax Ships

In addition to the raise in index R for all passenger ships, also the WOD-mechanism stemming from SLF 55 for a more strict calculation procedure of the survivability factor, s_i, for ro-ro passenger ships, whenever the respective damage case under consideration involves a vehicle deck, has been incorporated into the SDC 3 proposal, [13]. Nonetheless, it has been indicated by EU COM that for ships trading between EU ports, compliance must still be demonstrated also with regard to the Stockholm Agreement as it is prescribed in Directive 2003/25/EC, [2].

2.4 Specific Requirements for SP Ships

It could be noted that a corresponding raise in safety standard to a "societal acceptance level" for Special Purpose Ships has not been deem as necessary. Hence, for the purpose of calculating the required subdivision index for SP-ships the equation as provided in the present Regulation 6 of Chpt II-1 of SOLAS 2009 is retained, [13].

3. SURVIVABILITY FROM HOLISTIC PERSPECTIVES

In the statutory context of ships' stability, the expression "Survivability" is normally assigned to the s-factor as defined in SOLAS II-1 Reg. 7-2, in which s_i accounts for the probability of not to capsize within 30 minutes in a specific sea state after flooding the compartment or group of compartments under consideration. Nonetheless, for the purpose of the present study the expression "Holistic Survivability" simply means the ability to control and mitigate the risk of loss of life on-board a passenger ship and entails both inherent as well as operating conditions.

Even though a significant part of the survivability of a passenger ship is composed of an adequate degree of inherent safety, e.g. a built-in capability to withstand collision or grounding without catastrophic consequences, as stipulated in the statutory requirements, the total safety of a ship from a holistic perspective is to a large extent also depending on a number of other elements, such as:

- Operational Considerations / Trading Area
- Proactive Safety Management
- Decision Support
- Emergency Safety Procedures
- Evacuation Procedures

The above listed elements are all addressed in relevant chapters of the ISM Code and play a paramount role for breaking the chain of events during the development of an incident/accident before reaching an irreversible level.

As structured way of assessing conceivable chain of events which may eventually lead to an irreversible stage when the risk of loss of lives is inevitable, is presented in Figure 2, below, in which levels for different consequences during the escalation of an accident and required corresponding control and mitigation actions are presented.

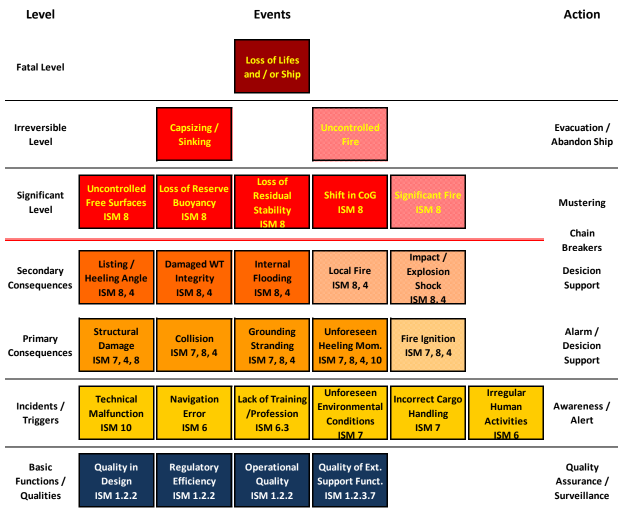

Figure 2: Matrix for a Holistic Assessment of Safety Management

The matrix as was initially developed by the DESSO Project, [15], but has been expanded to also include applicable regulations of the ISM Code. Obviously the matrix can be further developed, but still in its present form, it facilitates the understanding of vulnerabilities in survivability from a holistic perspective and might further be used to illustrate what proactive safety work is needed in order to enhance the holistic survivability.

4. FINDINGS AND CONCLUSIONS

With reference to the Swedish Triple-Helix study on ro-ro passenger ship safety from a holistic perspective, [1], and to the development of the regulatory framework as outlined in the above, some findings and conclusions are presented in the below sub-sections.

4.1 Proposal for new formulation of index R

Based upon the experience of at least some of the few ro-ro passenger ships built to SOLAS 2009 it can be concluded that the methodology to take into account the effect of Water on Deck (WOD) referred to as the Stockholm Agreement (SA) normally governs the design. Hence, it seems reasonable to conclude that SA allows for some margin with regard to the requirements of SOLAS 2009 that justifies a corresponding raise of the required subdivision index R, see Figure 3.

4.2 Influence of the SLF 55 WOD-mechanism

In addition to the raise of index R the proposed amendments to SOLAS II-1 are in part also based on the WOD-mechanism as proposed by SFL 55, in which a more strict procedure for the calculation of the survivability factor, s_i, is to be applied for ro-ro passenger ships, whenever the respective damage case under consideration involves a vehicle deck. The graph in Figure 3 illustrates the consequences for some few existing ro-ro passenger ships built to SOLAS 2009 and in compliance with SA. For one of these ships, a 600 persons RoPax built to SOLAS 2009+SA, the subdivision index margin emanating from SA has been presented. Moreover, the influence of an indicative 3% subdivision index reduction due to the SLF 55 WOD-mechanism has been plotted in the graph.

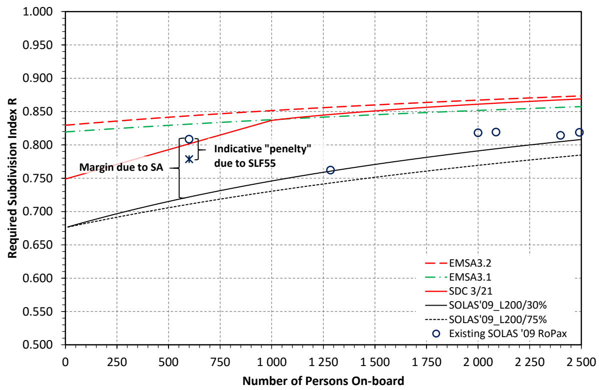

Figure 3: Graphical representation of consequences for some SOLAS ’09 ro-ro passenger ships in relation to proposed new formulation of index R

In addition to a pronounced spread, e.g. 3-12% in terms of index A-reduction as reported in the Danish study, [12], in the opinion of the authors the effect of the SLF 55-proposal is rather unclear. The results of the Swedish study, [1], show that when applying the SLF 55 WOD-mechanism; for damage cases of lesser extent resulting in a limited loss of buoyancy and hence rendering a relative high residual freeboard the most effective Risk Control Option, RCO, would be an increase in G’M, see Figure 4. Whereas for damage cases of larger extent where the residual freeboard is relatively low or even negative, the most effective RCO would obviously be to increase the original freeboard, see Figure 5.

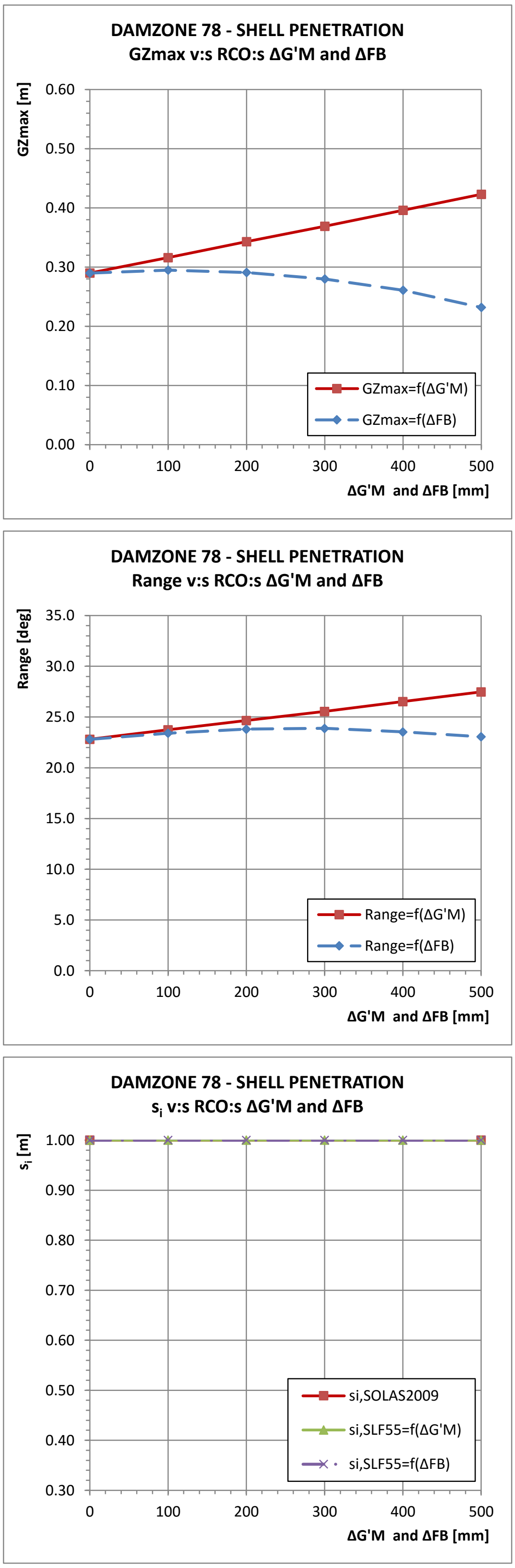

Figure 4: Evaluation of influence of the RCO:s ΔG'M and ΔFB when applying the SLF 55 WOD-mechanism – Damage Cases of lesser extent, [1]

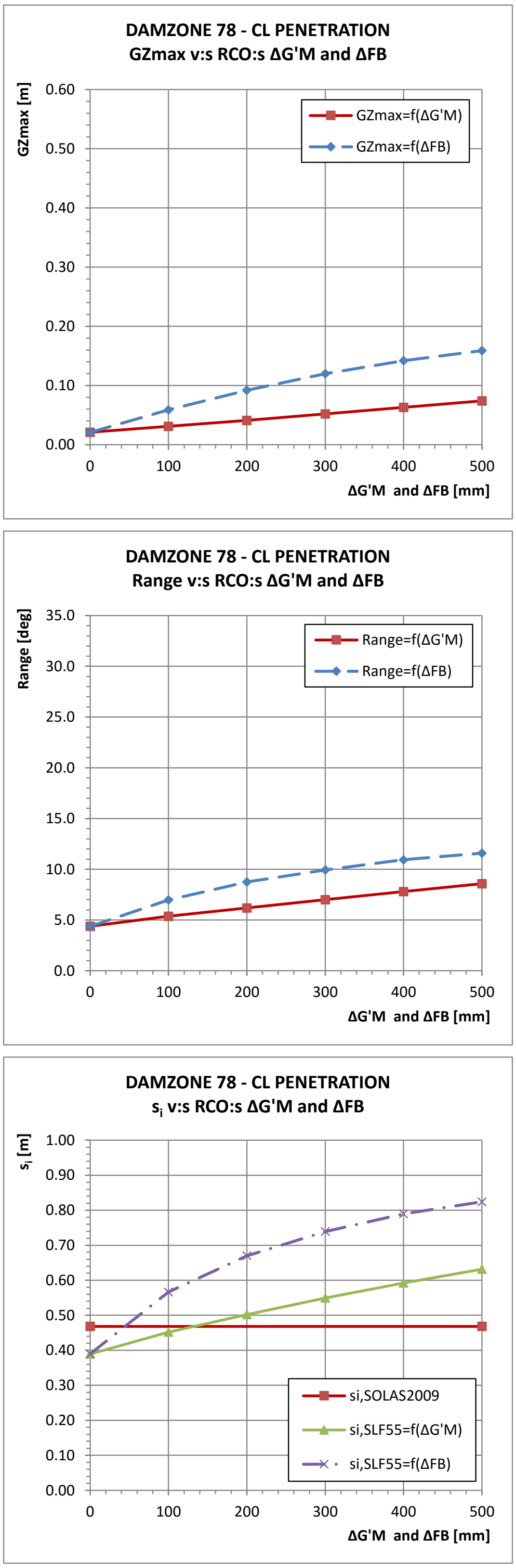

Figure 5: Evaluation of influence of the RCO:s ΔG'M and ΔFB when applying the SLF 55 WOD-mechanism – Damage Cases of larger extent, [1]

However, as the attained subdivision index A is composed of the product sum of the probability factor, p_i, and of the survivability, s_i, for all damage cases, the respective damage extension probability distribution evidently plays some role in the overall outcome. Nonetheless, whenever the influence of the vertical probability distribution factor, v, is comparably high, it seems reasonable that the SLF 55 proposal will stimulate to some degree an increased freeboard height for new designs.

While the WOD-mechanism of the Stockholm Agreement is directly related to the residual freeboard, the SLF 55 WOD-mechanism is based on the characteristic of the GZ-curve up to 20 deg. in terms of the survivability factor s_i. Hence, in addition to the residual freeboard, the SFL 55 WOD-results are also strongly related to the metacentric height, G'M.

The EU proposal, [11] for a new formulation of index R is based upon the results of the EMSA 3 study, but also datasets from a German Study, [9], from the GOALDS project, [5], [6], [7], and from a Danish study, [12] have been considered. The later study encompasses six smaller ro-ro passenger ships for which the loading conditions have been modified, all of which resulting in increased metacentric heights, in order to attain compliance with the proposed new level of index R while applying also the SLF 55 WOD-mechanism. It could be noted that the G'M-values, as reported for some cases of this study, might render high lateral accelerations resulting in secondary problems for passengers, crew and for the securing of cargo.

Moreover, for a given set of hull lines, in particular a constant KM-value, an increase in freeboard renders a decrease in G'M due to the vertical shift of the payload on the bulkhead deck and consequently a decrease in the survivability factor s_i. Hence, for a constant "business case" it seems reasonable to assume that the proposed raise in index R together with the reduction of index A due to the SLF 55 WOD-mechanism, will impose wider beams of future ro-ro passenger ships.

In addition, it should be noted that the application of the existing Stockholm Agreement includes an operational aspect in terms of a sea state defined by the significant wave height H_S up to which the ship under consideration is intended to operate. In many cases, due to the respective trading area, ro-ro passenger ships are designed for a significantly lesser sea state than represented by H_{SCr} = 4.0m (a first quick inventory reveals that approximately 50% of the ships operating in the Baltic region are designed for H_{SCr} < 4.0m). This aspect is cancelled out by the implementation of the SLF 55 proposal.

It has also not been perfectly clear within the Swedish project, how the influence of Barriers on the Vehicle Decks will be taken into account within the when applying the SLF 55 WOD-mechanism. Even though obstructions on vehicle decks are normally avoided as far as practicable, the arrangement of WOD-barriers must be considered as a rather efficient RCO, and may for some cases constitute the only viable option to enhance the WOD-characteristics.

4.3 Influence of Lower Holds

It could be noted that none of the four generic ro-ro passenger ship designs constituting the basis for the EMSA 3 study were arranged with lower holds. Hence, the influence of lower hold arrangements, which when arranged normally provides for about 15% of the payload capacity, has not been considered in the proposal for a new formulation of index R. However, as indicated in Figure 3, from the attained index A for the 600 persons SOLAS 2009+SA ro-ro passenger ship which actually is arranged with a lower hold, it seems reasonable to assume that some payload capacity may be arranged in lower holds also in a future perspective, at least for the "smaller" ships. Nonetheless, for the relatively large ro-ro passenger ships arrangements of lower holds seem not to be feasible in a future perspective. Consequently, for a constant "business case" this payload needs to be carried on higher decks, yet again imposing an increased beam to compensate for the loss of G'M and/or to accommodate for the stowage of the payload. Alternatively, a reduced dwt-capacity may have to be accepted.

4.4 Inclusion of RCO:s to mitigate Collision+ Grounding Damage Scenarios

As indicated in Figure 1 in the above, the proposal for a new formulation of the index R includes investments in RCO:s to account also for grounding/raking damages, even though the EMSA 3 project itself has acknowledged that the calculation methodology for grounding damages is still not mature enough to be implemented in a regulatory framework. The justification for adjusting the index R curve between the collision level and the collision + grounding level is based on a reasoning that for the examined cruise ships grounding/raking represents a significantly higher risk than collisions and that there is a clear trend that RCOs improving the attained index A for collision would also improve the attained index A for grounding. Nevertheless, in the opinion of the authors, it seems somewhat difficult to acknowledge the same trend for ro-ro passenger ships as these ships by necessity are arranged as to minimize asymmetries resulting in pronounced list following a damage. Thus, it is difficult to recognize that any grounding/raking damage scenario that would significantly differ from a corresponding collision damage. However, in the opinion of the authors, if such a damage case would anyhow be identified it should be adequately addressed by the existing regulation 7.5 and 7.6 in SOLAS II-1, which in principle are related to arrangement of wing tanks and vertical extent of damage assumptions while taking into consideration also damages of lesser extent.

4.5 Holistic Perspectives

Whenever new regulations are introduced it is obviously of vital importance that these regulations are compatible and coherent with relevant requirements of other instruments or codes and that necessary consequential amendments are developed. Explanatory notes and unified interpretations must to the furthest degree be present at entry into force. Even though a large amount of work has been successfully completed, it is noted that some efforts still remain, e.g. such as arrangements and control of WT doors and of essential systems.

In addition, as long as compliance is required also with the WOD-mechanism as set forth in the Stockholm Agreement, [2], which originates from a deterministic assessment of prescriptive damage assumptions, it might be difficult to utilize in full the so called freedom for the designer that has been argued to constitute one of the main objectives for implementing a goal based standard in terms of the probabilistic damage stability doctrine.

Moreover, since the probabilistic damage stability calculations are pertinent primarily to the inherent safety standard of a ship in terms subdivision and the overall result of the assessment is presented as an attained subdivision index A, it seems reasonable that utmost efforts must be made as to provide to the crew comprehensive yet unambiguous information about the ships ability to withstand all relevant damage scenarios, for all representative loading conditions. An adequate decision support is obviously vital when immediate actions must be taken in order to break the chain of events during the escalation of an incident / accident, or in worst case if evacuation is deemed necessary.

The importance of other factors than "safety-by-design" such as operational limitations and guidance has also been recognised within the development of the second generation intact stability criteria, [14].

5. ACKNOWLEDGEMENTS

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