SOLAS 2009 STABILITY REQUIREMENTS: IMPLEMENTATION

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SUMMARY

January 2009 saw the introduction of substantial changes to SOLAS, commonly referred to as SOLAS 2009. Not only have significant parts of Chapter II-1 completely changed, but so have the methodologies for assessing survivability of certain ship types.

This paper provides an overview of some of the main topics and how Lloyd's Register is adapting to provide necessary industry solutions and support, immediately and into the future. It provides an insight into the probabilistic requirements, our approval processes, developments and our participation in defining industry standards.

It is evident in this paper that the discussions predominantly revolve around passenger ships. This is due to their complexity and the conflict between the new regulations for survivability assessment moving from a restrained deterministic requirement to a risk-based probabilistic solution. It also highlights real issues over the difficulties of implementing this methodology. This conflict in overall design is less pronounced for dry cargo ships, which did not have to comply with a general damage stability standard until 1992 when the probabilistic concept was introduced for dry cargo ships only. Under SOLAS 2009, a modified requirement has been implemented. However, the fundamental issues remain the same.

NOMENCLATURE

A	Attained index.
A_s	Attained index at deep subdivision draft.
A_p	Attained index at partial subdivision draft.
A_l	Attained index at light service draft.
R	Required subdivision index.
p_i	Probability of a compartment or group of compartments being flooded.
s_i	Probability of survival after flooding.

1. INTRODUCTION

The SOLAS 2009 harmonised damage stability regulations under Chapter II-1 have been a long time in development. On January 1, 2009, the new damage stability regulations came into force under IMO Resolution MSC.216(82) with supporting explanatory notes contained in IMO Resolution MSC.281(85).

Probabilistic damage stability was introduced for dry cargo ships greater than 100 metres in length from 1992. At that time, a proposal was put forward at the IMO to extend this method of damage stability to passenger ships as a replacement for the existing deterministic requirements.

On the platform of the extensive work carried out by the EU funded HARDER project, existing statistical casualty databases were updated, substantial model testing was carried out and methodologies were reviewed to arrive at the new SOLAS 2009 requirement we have today. The intent was to provide a harmonised system for determining survivability for dry cargo and passenger ships, while maintaining the current and accepted level of ship safety. In a pure sense this is quite simple but the huge variation in ship configuration and operations, together with varying associated levels of acceptable and perceived risk, ensure this task is not so straightforward. Figure 1 demonstrates how existing regulations were encompassed into the new SOLAS 2009.

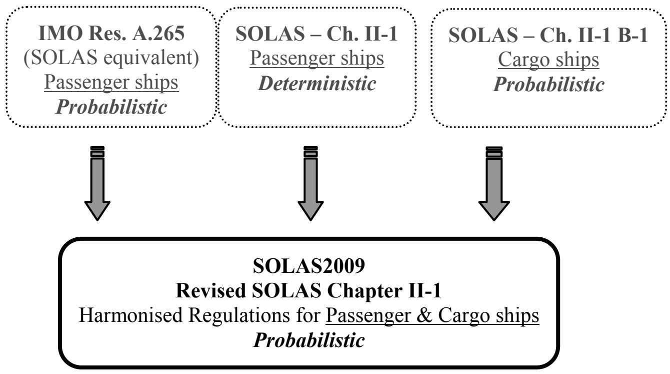

Figure 1: IMO development of SOLAS 2009.

IMO Resolution A.265(VIII) was introduced in the 1960s and provided an alternative option for passenger ship survivability assessment under SOLAS 90 (i.e. SOLAS 74, including amendments pre January 1, 2009). This regulation was ahead of its time in using a probabilistic approach. For passenger ships in general it proved unpopular and stringent, which explains why developments over the past 40 years focused around improvements and amendments to the deterministic SOLAS damage stability requirements. Resolution A.265(VIII) has generally been applied to vessels with a limited number of passengers and with lower holds where the main transverse bulkheads do not extend uniformly up to the bulkhead deck continuously from side to side, making it difficult to comply with the floodable length requirements. The new SOLAS 2009 has been formulated generally using the same approach as Resolution A.265(VIII).

2. PROBABILISTIC DAMAGE STABILITY

2.1 THE PROBABILISTIC METHOD

A probabilistic methodology has been accepted as the way forward in applying a unified approach to assessing the survivability standard for varying ship types. Certain vessel types have not been immediately introduced into the regulations due to operational characteristics (for example, offshore supply vessels); pollution (tankers); or basic hull design (offshore drilling units, high speed craft). These aspects need to be further analysed before harmonisation can take place.

In applying the probabilistic method, the Required Subdivision Index, R, level has generally been based on calculations of the attained index of sample ships to provide an equivalent level of safety to that achieved under the previous SOLAS 90 requirements. It is a simple formulation based on ship length and passenger numbers.

The accepted principle is that survivability increases with length and passenger numbers. Therefore, the new regulations have two formulations; one for cargo ships and the other for passenger ships. Cargo ships, for example, have an increase in the required index from 0.394 to 0.717 in the ship length range between 80 and 300 metres. Passenger ships follow a similar trend, but with passenger numbers included in the formulation.

Some difficulties were encountered in designing the R factor for passenger ships due to the limited amount of actual damage case data and the impact of a defined, as opposed to non dimensional damage, length used in the previous SOLAS regulations. During the development of the new framework, some inconsistencies in the deterministic requirements were found and this resulted in a mandate from the IMO's Maritime Safety Committee (MSC) to raise the safety level for passenger ships.

There are many factors relating to the risk of a ship sustaining and surviving a collision at sea; for example, loading, sea state, permeability, internal configuration and cargo shift. With good judgement and analysis the affect of these factors can be quantified to formulate an index. The location and extent of the damage is random but the probability can be defined by experience from damage statistics. The ability to survive is assessed on the characteristics of the ship form itself. This is represented by the attained Subdivision Index, A, calculated using measures of subdivision such as the probability that a collision will result in the flooding of a certain compartment and/or adjacent compartments, plus the ability of the vessel to display sufficient residual buoyancy to survive.

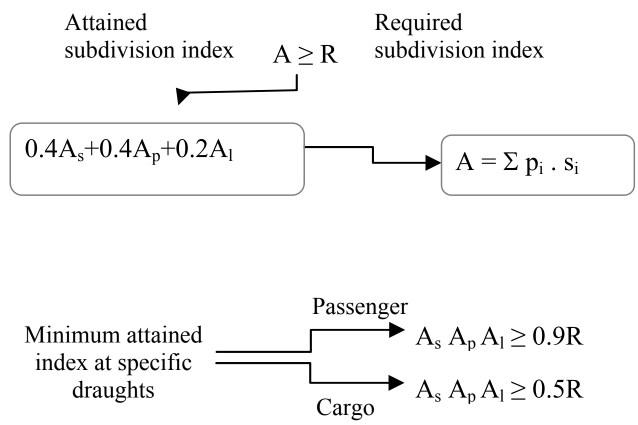

Figure 2: Description of the probabilistic method.

The index is obtained by the sum of indices calculated for the ship at three arbitrary conditions at the subdivision, light service and partial draughts.

$A = 0.4A_s + 0.4A_p + 0.2A_l$

The non-dimensional damage length, or p_i factor represents the probability that a compartment or groups of compartments may be flooded, disregarding horizontal subdivision. It is based on the examination of collision cases in which information, on both damage penetration and damage longitudinal extent, was available.

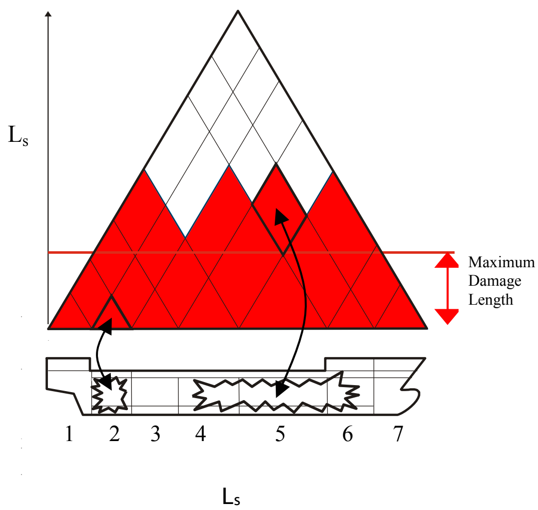

Figure 3: Representation for probability of flooding along the ship's length with seven zones.

The formula for the survivability factor, s_i, is a general formulation designed to represent the probability that the ship may survive after flooding of a compartment or group of compartments. The factor s_i is a generalised expression of the probability of representing all risks, including transient, intermediate stages of flooding and progressive flooding effects. To a certain degree it also implicitly covers characteristics such as the probability of ship survival with water accumulation on deck relevant to ships having large undivided continuous spaces, such as Ro-Ro vessels and dynamic wave effects. This particular aspect remains a topic for research and debate.

This general formulation is recognisable in the traditional sense by defined righting lever (GZ) parameters, such as maximum heel angle, minimum range and minimum height for intermediate and final stages of flooding:

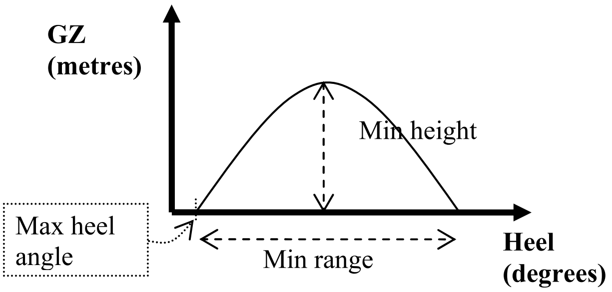

Figure 4: Representation for probability of survival after flooding.

Since s represents cumulative probability distributions, it is difficult to define what this figure means in real terms. For example, if s equals 1 we can say that the vessel has a very high probability of surviving a damage case in wave heights of up to 4 metres. On the other hand, if s has a value of 0.8 we do not easily know which probability is deficient or what the associated distributions are. Herein lies a fundamental and core aspect of dealing with future developments in the regulation.

For passenger ships, a deterministic calculation has been added to ensure that all passenger ships retain the capability to sustain minor damage cases along their full length and still meet the currently accepted minimum levels of heel and residual stability.

2.2 PASSENGER SHIP DESIGN ISSUES

For a modern passenger ship, the damage cases required for evaluation of the Attained Index, A, can run into many thousands. The index alone includes results from 200 to 300 selected cases. As a result, the time taken to complete the whole calculation process is substantially increased. Intermediate stages and cross flooding add to the complexity of the calculations. For example, small cruise ship designers can experience up to 15,000 damage cases taking up to 12 hours of computing time.

The margin line is no longer used as the flood limit restriction. The new regulations use horizontal escape routes, emergency control spaces and openings such as vents, doors and air pipes to determine the maximum intermediate and final equilibrium water planes after damage. This makes these areas much more important in the initial design stages of a passenger ship.

Services are no longer protected by one fifth of the breadth relative to the maximum inboard damage extent applied under SOLAS 90. For passenger ships with complex piping systems, these must now be designed to prevent progressive flooding from damaged spaces associated with positive contributions. A probabilistic approach, however, allows for more diversity in compliant bulkhead arrangements. This is somewhat restricted by deterministic elements in the new regulations for side and bottom protection, along with the current application of the regional Stockholm Agreement covering water on deck for Ro-Ro passenger ships, which is based on the traditional deterministic SOLAS 90 and associated B/5 (breadth) longitudinal bulkhead protective locations.

2.3 CARGO SHIP DESIGN ISSUES

In the case of these ship types, the transition to SOLAS 2009 has had an impact, particularly on vessels such as Ro-Ro ships and car carries. This is due to the revised statistics and alterations in application, the most notable being the increased height in the maximum damage height and more onerous permeability values. Increased requirements for double bottom heights have also had a particular impact.

2.4 SPECIAL PURPOSE SHIPS

Under the 2008 SPS Code – Code of Safety for Special Purpose Ships, 2008 Resolution MSC.266(84), stability requirements for these ship types have been updated to reflect the new SOLAS 2009 probabilistic damage stability regulations. This Code includes research/survey ships, certain vessels processing living resources from the ocean and those which normally have many persons on board.

The previous regulations adopted a passenger ship approach where ‘special personnel’ numbers on board were above 200. This has changed to requirements solely based on the passenger ship calculations. The reason behind this is that the basic formulations between cargo and passenger ship types under the new harmonized system are not the same and therefore do not allow a meaningful interpolation between the two. In reality these ships are used for a variety of purposes. Appropriate safety standards have to be in place considering operational practicalities such as able personnel, how many persons are onboard and what training is received The new regulations not only implement a more complex method of calculating damage stability but in certain cases require more onerous ‘passenger’ ship related requirements.

3. PLAN APPROVAL

3.1 EXPLANATORY NOTES

The IMO published Explanatory Notes to SOLAS 2009 Chapter II-1 under Resolution MSC 281(85). These notes support the regulations and have been designed to give precise information. As a result, many additional items and proposals that were discussed by the drafting group are not included. Proposals have also been made to include these as mandatory but this has not yet been agreed.

3.2 GENERAL PROCESS

The appendix in part B of the Explanatory Notes gives information on what should be submitted for approval. Obviously, approval authorities will have some variations on this. What is apparent, especially with complex designs, is the need to ensure that the submission serves as a snapshot at the time of submission. Bearing in mind the numerous items to be covered (systems, structural fire protection etc), any associated plans should be as consistent as possible in order that subsequent discussion items can be easily identified and replicated by the designer and approval authority.

Although Lloyd's Register uses NAPA as its review tool, submissions are also received using other software products and solutions. In these cases we have to have the ability to not only identify any disparities in the results but to define where the discrepancies lie. Our experience, such as development of our in-house statutory computational managers (SCMs) mentioned later in this paper, provide us with this ability.

First and foremost, it is important to validate the model and take a disciplined approach, especially for complex designs. Not only is watertight subdivision considered but also items such as A Class fire bulkheads, openings, cross flooding sections, permeabilities, horizontal escape routes, access hatches, emergency switchboard rooms, weather tight openings, air pipes and so on.

Class Rules require that maximum head of water resulting from the damage stability calculations is considered when determining the strength of the ship. As a result, the designer has to have a good idea of the stability characteristics and ensure suitable margins are in place at a very early stage of the design process.

Compartment connections must be carefully considered. In passenger ships, certain compartments will be flooded instantaneously, while others will flood in various phases and stages. Due care needs to be taken of flood directions and sequences, finally checking to ensure that generated calculation results are logical.

3.3 SUBDIVISION TABLE

This table determines the extent of all the zones and position of internal subdivision for addressing the probability distributions based on the ship dimensions (i.e. 'p_i' as shown in Figure 3) This, together with the watertight subdivision plan, forms part of the necessary basic information required to be submitted for plan approval. The subdivision table does not necessarily follow physical boundaries and can be used as a means to take on a reduced 'p' probability value in favour of providing a protective location for piping, for example, in order to reduce the number of valves. Automatic damage case generation is based on this table. This process can prove extremely lengthy without an automated system. Of the many cases generated, those with the most onerous 's_i' factor in relationship to 'p_i' will make up the contribution to the attained index, A.

3.4 WEATHER TIGHT AND UNPROTECTED ITEMS

As mentioned, no margin line is defined in SOLAS 2009 to limit stability margins after a flooding scenario. This is defined by items such as openings, horizontal escapes, pipes and emergency switch rooms. These are treated in different ways depending on their application and construction. Generally, they fall into the categories of weather tight and unprotected items. Accordingly, these may or may not be submerged in final, intermediate stages or within the required residual buoyancy range required to achieve a contribution to the index.

Many systems are not considered until later in the design stage and so the designer must make provisions and think carefully how to ensure that adding, for example, air pipes close to the hull shell at a later stage will not have a detrimental impact to the subdivision calculations later on in development. Additionally, where these systems are complex, thought has to be given to their construction and how to provide suitable information at the shop floor to ensure installations are in the right place and quality surveys procedures are maintained. Ad hoc alterations and re-routing can easily have an impact on compliance.

Escape hatch openings are to be designed such that when leaving an undamaged space the hatch opening is not situated in a flooded area. For passenger ships, horizontal escape routes which form part of the main escape routes up to the muster stations also require protection from flooding. It is easy to focus on modelling the regulation precisely as opposed to questioning the intent. For example, towards the forward and aft ends of a cruise liner an escape hatch opening may not be in such close proximity to an immediate access upwards or protected horizontal escape area. Considering questions like these is a necessary process in the plan approval process today and requires close liaison between the designer and approval authority.

3.5 CROSS FLOODING ARRANGEMENTS

Recommendations for a standard method for evaluating cross flooding arrangements have been adopted under IMO Resolution MSC.245(83). This is to cater for aspects in Chapter II-1 dealing with these points.

Difficulties arise in the calculations in that the measure of survivability is driven by achieving contributions to the attained index. Therefore, the objective is to arrive at a satisfactory 's' or survivability value when considering a particular damage case with associated delayed flooding, rather than a final equilibrium position after all cross flooding has taken place. The flow rate through the aperture needs to be considered, together with how to address non watertight boundaries that are of sufficient strength to seriously restrict the flow of water. Specified time limits of within 60 seconds for instantaneous flooding, or a maximum of 10 minutes to a specified 'equilibrium', add to difficulties in arriving at suitable solutions to reflect the regulations, especially when considering multiple compartment damages with several cross flooding scenarios. Questions arise, such as:

At what stage is cross flooding applied as opposed to progressive flooding?, and

Is the software used robust in this application or is an alternative solution better suited?

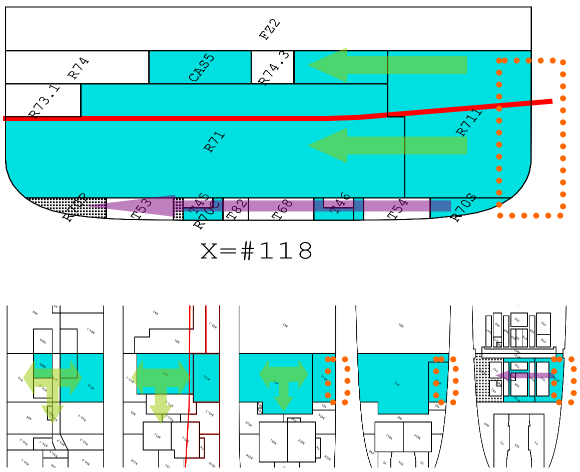

Figure 5: Example of complex flooding scenario in 1 zone only following starboard damage case.

4. STATUTORY COMPUTATIONAL MANAGERS (SCM)

4.1 INTRODUCTION

To speed up the stability plan approval process, while implementing a quality system at the same time, Lloyd's Register has been developing and marketing statutory computational managers (SCMs) to deal quickly and efficiently with damage stability calculations. These have been designed on the NAPA platform which is the predominant software used by the industry and Lloyd's Register alike, particularly for probabilistic stability evaluations. Running detailed models (including escape routes, cross flooding, emergency control stations, A Class fire divisions, various openings, and MARPOL oil outflow) through our managers gives us and the client, immediate confidence in the model verification and interpretation process. Advanced options are provided and the full functionality of the advanced NAPA commands remain accessible where required for more detailed review. A substantial reduction in the review process time is achievable.

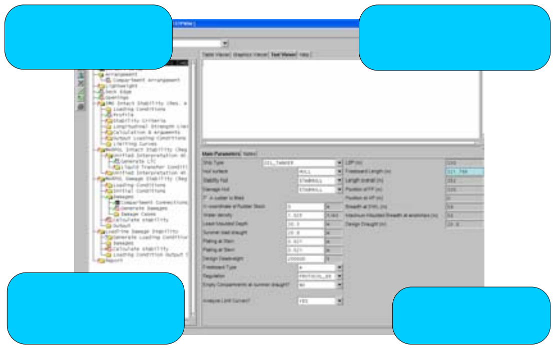

Figure 6: SCM benefits.

4.2 BENEFITS

For our clients investing in these managers, they can gain the following advantages:

- A right-first-time solution.
- Reduction in errors through missing applicable regulations or being unaware of new regulatory developments.
- A practical training aid.
- Reduced time from concept to delivery with Lloyd's Register providing assistance in the design cycle.
- Reduced cost to the designer with fewer changes required in the approval stage.

The managers are an effective tool, especially when considering the lengthy calculation processes that may be required. Producing managers to encapsulate SOLAS 2009 probabilistic requirements has been a mammoth task. The logic behind the interpretations of the regulations has to be considered in their entirety as opposed to a specific ship or item. Therefore, when dealing with our clients concerning a particular regulation we have also considered the implications holistically to ensure we can maintain a consistent approach into the future for all relevant ship types. Other considerations are that designers can tackle these requirements in numerous ways, and we need to have an adaptable platform to cope with these variations. This detailed knowledge further supports us in reviewing submissions made using other tools and methods.

4.3 IMPLEMENTATION

To date, managers have generally been released to deal with ships such as tankers and bulk carriers under version 2009.1.

The probabilistic managers have been developed and are currently being tested ready for release in the near future.

5. FUTURE DEVELOPMENTS

5.1 THE IMO SLF SUBCOMMITTEE

Lloyd's Register is actively involved with the IMO subcommittee on stability and load line and on fishing vessel safety (SLF subcommittee) via the working and correspondence groups. We provide technical advice to flag administrations and recognised associations. This service is invaluable as we act as a conduit between the highly academic community and the industry in providing support. The experience gained via our in-house developments is fed back to the industry via the working and correspondence groups and therefore supports the industry as a whole. In doing this we maintain our knowledge and experience at all levels.

The main developments at IMO SLF in ship survivability for the near future are covered by the following items which are currently in the SLF agenda:

5.1 (a) Guidance on the impact of open watertight doors on existing and new ship survivability

This item concerns passenger ships where at specified times watertight doors may be allowed to remain open for necessary operational reasons. Difficulties arise in developing a survivability standard corresponding to the operational, construction and location parameters of the doors themselves.

Deterministic solutions are being proposed to tackle flooding scenarios. A review after the initial plan approval process is complete could prove a costly exercise in revalidating the ship model in order to carry out the review.

Lloyd's Register's involvement is in assisting with comments via the working group to arrive at a suitable technical proposal. The deadline for resolving this agenda item is 2011.

5.1 (b) Stability and sea-keeping characteristics of damaged passenger ships in a seaway when returning to port by own power or under tow

The IMO agreed in 2000 that future large passenger ships should be designed based on the principle that a ship is its own best lifeboat. It was recognised that with vessels designed to carry ever increasing numbers of passengers the task of retrieving people in lifeboats from the ocean is a significant problem.

The instruction from the IMO was that vessels should either be capable of returning to port or able to survive for three hours to allow for a timely evacuation.

The new requirements will be applicable to all passenger ships built on or after July 1, 2010, having a length of 120 metres or having three or more Main Vertical Zones. This particular size criterion was set, as it was felt that ships below this limit would be very difficult to design with the required operability of systems in a practical manner.

A substantial part of theses regulations deals with the complexities of system requirements for retaining people on board a distressed ship with the additional capacity to return to port. There are two casualty categories; namely, fire and flooding

Work is ongoing at the IMO to develop appropriate requirements for survivability and provision of a safe platform for evacuation following a flooding casualty.

Guidance on information to be provided to the Master is currently being developed. As the harmonised methodology has developed as a design tool, the results do not provide information relevant to the Master in a real casualty situation. The developed guidance will provide assistance on how to ascertain the immediate condition of the vessel and, if satisfactory, what procedures are necessary for a safe voyage back to port.

In co-operation with the major Euroyards, Lloyd's Register provided details (SLF 51/11/1) on the effects of various criteria as applied to a methodology for defining a practical stability casualty threshold for safe return to port.

5.1 (c) Time-dependent survivability of passenger ships in damaged condition

This is in response to the ability for a ship to survive for three hours to allow for a timely evacuation as mentioned in 5.1(b) for safe return to port.

Lloyd's Register is not actively involved in this topic although we do have experienced staff with considerable experience from working on the HARDER project at European model tank basins and who follow these developments.

5.1(d) Damage stability regulations for Ro-Ro passenger ships

Following discussions at the European Commission by its member states concerning the Stockholm Agreement, which addresses water on deck for Ro-Ro passenger ships operating in European waters, it was agreed that this should be discussed at the wider forum of the IMO. This agenda item is to be completed in 2011 which is before the EU project GOALDS is due to complete in 2012. GOALDS and this issue are discussed below.

5.2 THE EU AND STOCKHOLM

It was considered that the Stockholm Agreement covering water on deck requirements for Ro-Ro passenger ships operating in the EU would no longer be required as this phenomenon is considered to a certain degree as implicitly included within the 's' or survivability function covered by the SOLAS 2009 requirements. In view of disasters such as the Herald of Free Enterprise,(Figure 7), this phenomenon remains an issue under review.

Figure 7. Herald of Free Enterprise

During the course of the development of the regulations at IMO, the SEM or static equivalent method was proposed as an additional measure for this purpose. (Indeed at the early stages of development it was proposed as a full methodology for evaluating both passenger and cargo ships alike.) This additional application proved difficult in providing consistent results and therefore was abandoned as a solution. A simple restriction to the minimum freeboard was also proposed.

Recent investigations have considered increasing the required GZ height for calculating the 's' values in line with original formulations considering these ship types, but it has been shown that this, in itself, has a negligible affect on the attained index.

The Stockholm Agreement provides a satisfactory solution, in conjunction with SOLAS 90 deterministic standards, but proves difficult to mesh with the probabilistic regime. On the basis of numerous studies, the EU member states are split on this complex issue of the effects of water on large open deck spaces and have agreed that it is best resolved via a wider exposure under the IMO agenda for the SLF sub committee. The excellent studies recently published in Europe show differences in assumptions and approach which make it difficult to determine the best way forward. Meanwhile, ships are being built in confidence by applying both the Stockholm and SOLAS 2009 regulations.

5.3 GOALDS

Project GOALDS (Goal based damage stability) started this year. It is an EU funded project under the FP7 framework program for research. It provides the ideal forum to be able to collectively investigate items, such as water on deck, with a uniform approach to see if the current formulations can be improved. The participants include the major European shipyards, flag administrations, universities, tank testing research establishments and classification societies. The project addresses some of the new challenges related to 'design for safety' and risk-based design and will involve research and development studies with the aim of improving the probabilistic damage stability formulations for large passenger vessels. The research programme will discuss technical issues related to improvement of ship survivability formulations and aims to develop a risk-based subdivision requirement for passenger vessels. Upon completion, GOALDS will submit key results to the IMO for consideration in the Rule making process.

The GOALDS key objectives are:

- To develop an enhanced formulation for the survival factor 's' introduced by MSC 216 (82) for the assessment of the probability of survival of large ROPAX and mega cruise ships in a damaged condition, based on extensive use of numerical simulation accounting for key design parameters of passenger ships and for the time evolution of flooding scenarios.
- To develop a new survivability formulation for flooding following grounding accidents.
- To integrate collision and grounding survivability formulations into a single framework.
- To validate the new formulation through experimental and numerical analyses.
- To develop a new damage survivability requirement in a risk-based context.
- To evaluate the practicability of the new formulation through a series of ship concept design studies.

Figure 8: Assessing collision data.

Our participation in this project not only leads to a more integrated and consistent knowledge set with our European colleagues, but it also enables us to maintain our ability to critically deal with state of the art solutions that may not be directly covered by our Rules and the regulations. It also means that we have a clear understanding of the implications when presented with the situation where what seems like a small amendment to a parameter in the regulation itself could have a possible and profound effect on the statistical distributions which is not explicitly evident.

This project is scheduled to take place over three years, after which the results will be presented to the IMO.

5.4 OTHER DEVELOPMENTS

For projects in which we are not involved, we look forward particularly to the results of the developments in the EU FLOODSTAND project also covered by the FP7 framework. This project is investigating more reliable information and modelling of ship flooding with a view to developing new methods for analysing the flooding extent on board, as well as new methods of comprehensive measures of ship damaged stability. This will resolve difficulties and unknowns in the flood water assumptions currently used for our damages stabilities regulations.

6. CONCLUSIONS

The latest set of survivability requirements mark a changed trend from deterministic to probabilistic methodologies, opening up the direction to risk-based platforms for assessment.

The new SOLAS 2009 regulations challenge designs for complex vessels such as passenger ships. The recent changes have had a marked effect on the physical designs; not only structurally but also on systems, closing appliances, fire protection, cross flooding and many other items, resulting in considerable cost increases.

Cargo ships have also experienced difficulties, with requirements such as increased double bottom heights and new permeability requirements marking step changes in series built vessels.

Time is needed to fully understand the implications of SOLAS 2009 on fundamental designs and already investigations are being carried out (e.g. GOALDS) to look at current issues that are being raised such as the effects of water on deck on Ro-Ro passenger ships.

Understanding the fundamental concepts requires a detailed knowledge of how the probabilities for the damage characteristics have been established, together with the associated applications implicitly included in defining the measure for adequate survivability. These items re-open fundamental and basic concepts of naval architecture.

Further developments in ship survivability requirements are on the cards, for both intact and damage stability assessment under varying conditions. For example, the IMO is investigating performance-based standards for assessing ships in the intact state and real time flooding for addressing ship abandonment following a casualty. As real-time modelling solutions become more readily available these will be used increasingly in the industry. At present these generally remain outside the basic regulatory framework. Due to their complexity, they are not so widely accessible and are costly. Having said that, the value and power of these tools is clear. Lloyd's Register is not currently active in this area but does have non-linear time domain tools such as PRETTI which, by virtue of its relationship to the CRS PRECAL group of programmes, can be used for analysing first order ship motions and sea keeping.

Lloyd's Register employs personnel experienced in aspects covering the HARDER project, IMO attendance and software tool developments. We pride ourselves in acting as mediators between the drivers of the academic world pushing ahead with the latest technology and the practicalities experienced by our clients in building modern state- of-the-art ships.

7. ACKNOWLEDGEMENTS

A sincere thank you to all my colleagues and friends in the industry for their support and many hours of debate and patience, without which this paper on the 'black arts' would not be possible.

8. REFERENCES

1. International Maritime Organization, 'Adoption of Amendments to the International Convention for the Safety of Life at Sea, 1974, As Amended', MSC Res.216(82), 8 December 2006

2. International Maritime Organization 'Explanatory Notes to the SOLAS Chapter II-1 Subdivision and Damage Stability Regulations' MSC Resolution.281(85), 4 December 2006

