FLOODSTAND – Overview of Achievements

Risto Jalonen, *Aalto University,* risto.jalonen@aalto.fi,

Pekka Ruponen, *Napa Ltd,* pekka.ruponen@napa.fi,

Andrzej Jasionowski, *University of Strathclyde (SSRC),* a.jasionowski@strath.ac.uk,

Pierre Maurier, *Bureau Veritas,* pierre.maurier@bureauveritas.com,

Markku Kajosaari, *STX Finland Oy*, markku.kajosaari@arctech.fi*,

Apostolos Papanikolaou, *National Technical University of Athens,* papa@deslab.ntua.gr

ABSTRACT

Project FLOODSTAND was targeted to develop and increase reliability of flooding simulations and assessments of passenger ship performance in safety-critical crises related to damage stability. Experimental tests and numerical studies, carried out in relation to the progress of flooding, are described. New approach to flooding simulation for onboard use has been developed. Some approaches to model the capsize as a stochastic process have also been studied, and uncertainties related to the "time-to-capsize" have been analysed. Mustering-Abandonment-Rescue process has been modelled using matrix-based obstacle model. Results of the project fill many gaps in previous knowledge related to flooding in passenger ships.

Keywords: *flooding, damage stability, leakage, collapse, capsize, time-to-flood, cross-flooding, evacuation, large passenger ship*

1. INTRODUCTION

FLOODSTAND, a collaborative 3-year EU-project coordinated by Aalto University (AALTO), was finished in February 2012. The project was focused on flooding in passenger cruise ships and ropax vessels. Emphasis has been put on topics like cross-flooding, leakage and collapse of non-watertight doors, effects of ship dynamics on flooding simulation, flooding progression modeling, sensitivity of the outcome of flooding on some selected parameters and flooding simulation and measurement onboard. Other main issues in the project are: time-to-capsize (ttc), uncertainty (related to the outcome of flooding) and rescue process modeling.

The project objectives and methodologies as well as the organizational structure applied were described in *Jalonen et al. (2010)*. Work packages WP1-WP3[1] followed a deterministic, bottom-up approach, whereas in WP4-WP7[1] more stress was laid also on the probabilistic approach. The interplay between both outlooks, merged together in FLOODSTAND, turned out to be challenging, but important, too, in this research project. In the following, an extensive overview of the most important results and findings of the performed research is presented.

---

[1] Work Packages and WP-leaders of FLOODSTAND:
WP1: Design and application (STX Finland Oy);
WP2: Flooding Progression Modelling (AALTO)
WP3: Flooding Simulation and Measurement Onboard (NAPA)
WP4: Stochastic Ship Response Modeling (SSRC)
WP5: Rescue Process Modelling (BV)
WP6: Standard for Decision Making in Crises (SSRC)
WP7: Demonstration (NTUA)

* Present address: Arctech Helsinki Shipyard Oy, Helsinki, Finland

2. MODELLING OF FLOODING PROGRESSION (WP2)

2.1 Pressure Losses in Openings and Cross-Flooding Devices

One of the project objectives was to obtain new information on pressure losses in openings and cross-flooding ducts. For manholes the effective discharge coefficient in various flow conditions was evaluated both with full-scale experiments at Aalto University and CFD analyses by both CNRS[2] and CTO[3].

The often applied discharge coefficient 0.6 was found to be a good approximation for the manhole in free flow conditions. The discharge coefficient of a full-scale manhole was mostly in the range between 0.58 and 0.59. In fully submerged flow, the discharge coefficients of the full-scale manhole were in the range between 0.67 and 0.70. The correspondence of CFD results and measurements was very good.

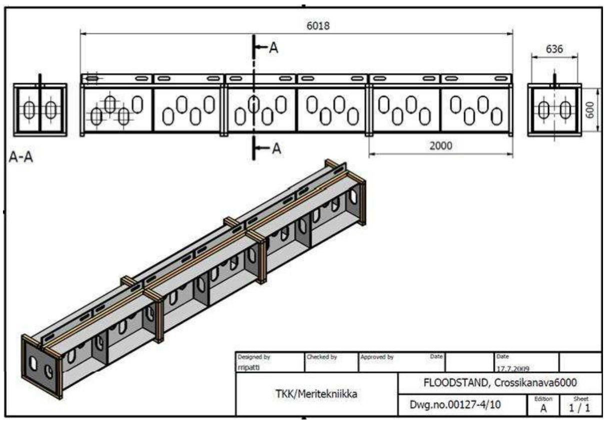


Figure 1: The 6 m long cross-flooding duct tested at Aalto University, Finland. Note! No stiffeners are marked here inside the duct.

Variations of a typical cross-flooding duct with two manholes in each girder were studied with large scale (1:3) model tests at Aalto University, Fig. 1. The test arrangement and the results are presented in *Stening et al. (2011)*. Comparative CFD calculations were done both in model scale and in full-scale by CNRS. The scale-effects were shown to be minimal. Also the effect of inlet pressure height was found out to be very small.

Comparison to the current guidelines, *IMO Resolution MSC.245(83) (2007)*, showed that application of the suggested regression equations may result in significant under-estimation (about 30%) of the pressure losses in the cross-duct.

In addition the pressure losses in two typical air pipe configurations were analysed with CFD tools at CTO. A summary of the research related to cross-flooding devices is presented in *Ruponen, et al. (2012a)*. The results have also been submitted to IMO for further consideration, *IMO SLF 54/4 (2011)*.

2.2 Effects of Non-Watertight Structures

Background for the research has been presented in *IMO SLF47/INF.6 (2004)*. The need to get better knowledge on leaking and collapsing of non-watertight structures has become more important as the time-domain flooding simulation tools have been taken into more frequent use.

A watertight tank to facilitate the tests with interchangeable structures under relevant water pressure and destructive loading was designed and built. It was fitted with a system for static water pressure adjustment and equipment for measurements and monitoring of the tested structure and for measurement of the leakage flow rate before the tested structure collapses.

Several different structures, such as both hinged and sliding fire doors, were tested, see Fig. 2. Many items were also tested to both directions. Comparative FEM analyses were also performed by MEC[4], Fig. 3, to obtain further details on the failure mechanisms.

---

[2] In this project the “Centre National de la Recherche Scientifique” (CNRS) represented Lab Mecan Fluides, UMR 6598 CNRS, Ecole Centrale de Nantes (ECN).

[3] CTO is the acronym for Centrum Techniki Okrętowej S.A. (Ship Design and Research Centre, in Poland).

[4] MEC is the acronym of MEC Insenerilahendused, a small Estonian engineering office concentrating on

Figure 2: Door tests in full scale at CTO's laboratory in Gdansk, Poland

Based on the test results, B-class structures do not significantly restrict flooding as the leakage was very significant even under small pressure heads. For A-class fire doors the critical collapsing pressure head ranged between 1.0 m and 2.5 m.

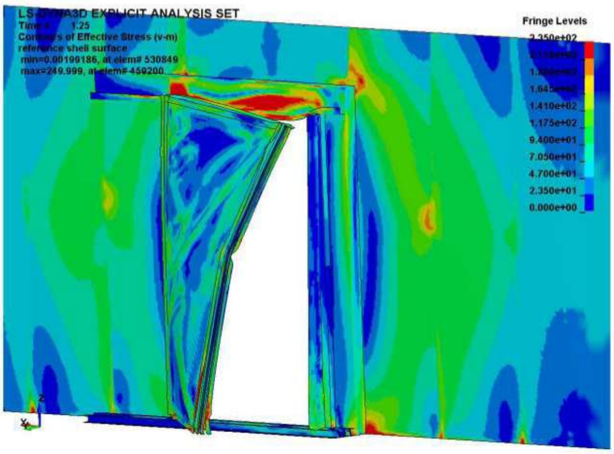


Figure 3: FEM analysis of the failure of a sliding fire door, MEC, Estonia

Based on the experimental and numerical research, guidelines for modelling leaking and collapsing structures in time-domain flooding analyses were developed. These have been presented in *IMO SLF54/INF.8/Rev.1 (2011)*.

2.3 Flooding Tests and Sensitivity Analysis

Dedicated mode tests on the detail level of modelling internal layout of the flooded compartments and the effects of air compression were studied by MARIN. Main outcomes and details of these tests are reported in *Ypma (2010)*. Furthermore, the sensitivity of flooding simulation results to the applied discharge coefficients and modelling of leaking and collapsing structures were studied, see *Karlberg et al. (2011)*.

3. FLOODING CONTROL AND DECISION SUPPORT (WP3)

3.1 Guidelines for Flooding Detection Sensors

For reliable flooding prediction the breach size and location need to be known. This is possible only if the ship is equipped with level sensors[5]. The flooding rates can be calculated based on the measurements, compartment geometry and floating position. And further the breach can be estimated based on the flow rates.

IMO has established some basic requirements for flooding detection systems on passenger ships, *IMO MSC.1/Circ.1291 (2008)*. A more comprehensive and detailed recommendation has been developed.

In summary the sensors should be placed so that the system can detect flooding before the stability of the ship is threatened. As parts of a decision support system, the sensors should detect flooding as early as possible. Moreover, the sensors should be placed so that the system is able to determine where the breach is located. In practice this means that normally each watertight compartment should have two level sensors in each watertight compartment on each deck below the bulkhead deck. The

---

advanced structural design and on (numerical) strength analysis.

[5] Continuous measurement of floodwater level

complete guidelines are presented in the Deliverable D3.3, *Penttilä (2012)*.

Level sensors are necessary for obtaining the required data for flooding prediction onboard a damaged ship. On/off switches may only be installed to small spaces (i.e. sealed compartments in double bottom) from which the flooding cannot progress to other spaces. This is much more than current standards. Also level sensor and flooding detection system should be adjusted so that there are no false alarms. Periodical checks for level sensors are also recommended.

3.2 Breach Detection Based on Sensor Data

The first idea was to use an inverse method for prediction of the breach size and location on the basis of level sensor data and short simulations. This was described in *Penttilä and Ruponen (2010)*. The results were promising but the method was a little too time-consuming, especially when considering that the available input data is rather rough. Therefore, a simplified but faster method was developed. All rooms with detected flooding (soon after the accident) are considered to be breached. The breach location is in the outer shell, extending from the bottom of the room to the top of the room. If the room is not connected to the hull surface, a hole (connected to the sea) is modelled on the bottom of the room. The breach size (area) is determined from the flow rate on the basis of the measurement data. The accuracy of the fast method for estimating the breach opening is presented by Ruponen et al. (2012b).

3.3 Prediction of Progressive Flooding

When the hull of a ship is breached due to collision or grounding, the floodwater enters the damaged compartments. Open doors and various pipes may result in progressive flooding to undamaged compartments, thus making the situation even more critical. Also before the final floating position the ship may pass through intermediate positions that are more dangerous than the final one. Thus for decision support it is necessary to check the whole process of progressive flooding. Within WP3 a completely new approach has been developed for prediction of progressive flooding. The details of the method are presented in *Ruponen et al. (2012b)*.

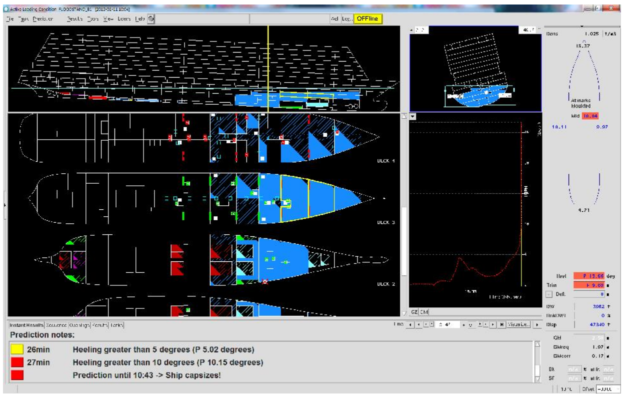
The developed method has been extensively tested against both experimental results from full-scale flooding of a decommissioned navy ship and dedicated simulations with the sample large cruise ship. This new approach is not time-accurate, but despite of this, the intermediate phases of flooding and time-to-flood are captured. As a part of demonstration work, the developed flooding prediction method was implemented into NAPA Loading Computer, Fig. 4. The flooding extent and the intermediate phases can be predicted in less than a minute for very extensive damage cases.

In addition, the effects of waves were studied by comparing fully quasi-stationary flooding simulation and combined approach with ship dynamics taken into account. The results have been presented in *Manderbacka et al. (2011)*.

4. TIME-TO-CAPSIZE (WP4)

A method for instantaneous classification of the severity of ship flooding casualty, was one of the issues covered. It was planned to be validated by a capsize tests, with the model of a ropax (Estonia) at SSPA, Fig. 5, and numerical simulations conducted with the same ship by NTUA.

In both studies a two-compartment damage at aft bulkhead of the machinery room, aft amidships was selected as the damage case that included the vehicle space damaged and getting flooded. More details of the experimental and numerical studies with the selected ship can be found in *Rask (2011)* and in *Spanos & Papanikolaou (2011)*.



Prediction notes:

🟨 26min Heeling greater than 5 degrees (P 5.02 degrees)
🟥 27min Heeling greater than 10 degrees (P 10.15 degrees)
🟥 Prediction until 10:43 -> Ship capsizes!

Figure 4: Flooding prediction tool for decision support, a schematic view on the user-interface with an example of a case, where open watertight doors (marked with red) lead to a rapid capsize. (Note! This figure is in reduced scale of the full size of computer screen!)

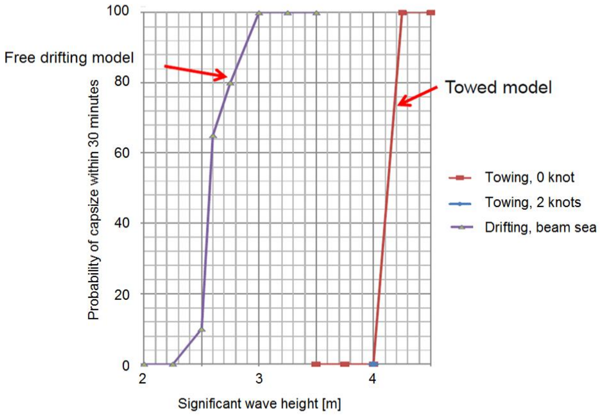


Figure 5: Probability of capsize within 30 minutes vs. Hs. The change from 0% up to 100% occurred for the free drifting ropax model in beam seas between significant wave heights Hs = 2.25m - 3.0 m. For the towed model in head sea it occurred at Hs=4.0m - 4.25 m. Results of the model tests at SSPA, Sweden, adopted from *Rask (2011)*.

The stochastic ship response modelling was developed on the basis of an analytical model and of a hybrid model as described by *Jasionowski (2012a, 2012b)*. Summaries of these reports include the following conclusions:

a) The case studies presented demonstrate that the extent of flooding, affecting parameters of GZmax[6] and Range[7], seems to be one of the most critical information needed for confident assessment of criticality of flooding situation. The precision or lack thereof in estimating the extent of flooding experienced during crises seems to be an overriding uncertainty datum, on the basis of which the epistemic uncertainties of the modelling itself should be considered acceptable for engineering purposes of decision making during crises.

b) It was concluded based on a case study undertaken, involving nine hundred numerical simulations for three flooding cases and three sea state conditions, combined with statistical inference on heel angle development and further inference on projected time to capsize that *no enhancement of accuracy of prediction of the situation evolution can be attained through observing initially developing angles of heel*. This is to say, that development of angle of heel of up to about 8 to 10deg, (among the three study cases), does not influence probability that capsize can occur over next say 30 minutes.

5. M-A-R MODEL (WP5)

Evacuating and abandoning a passenger ship implies a certain potential for hazardous situations, congestion issues, injuries and death of passengers. In order to assess the risk for passangers to abandon the ship this work package aims at studying the *Mustering*, *Abandonment* and *Rescue* (M-A-R) process.

5.1 Human Health Status

Health of passengers onboard the ship is modelled by a Human Health Status which is a continuous variable *h*, discretised into 4 states, Good Health, Minor Injuries, Severe Injuries and Deceased as described by *Nicholas et al (2010)*. The age of passengers is represented by

---

[6] GZmax: maximum positive righting lever (m)

[7] Range: range of positive righting levers beyond the angle of equilibrium (degrees)

the variable *a*, discretised in 3 ranges, [0; 50],]50; 75],]75, a_{max}].

$f(h,a)$ is the probability density function providing the probability of having a passenger in health *h* for a given age *a*.

5.2 Obstacles

The M-A-R process is a sequence of actions to perform in order to evacuate safely the entire population onboard from the general emergency alarm signal to the shore. Several sequences as defined in the FLOODSTAND Deliverables D5.3, *Maurier et al (2011),* and D5.4, *Maurier & Corrignan (2011)* depend on the means of escape (type of Life Saving Appliances, lifeboat or liferaft) and means of rescue.

For each potentially hazardous action an *obstacle* is defined that describes the probability of degradation of the human health status. The degradation of health associated to the obstacle *k*, D_k is defined as:

$$f_k(h,a) = D_k[f_{k-1}(h,a)]$$

D_k can be simplified after discretisation in three triangular matrices, one for each age range. Each Matrix can be found in the referenced FLOODSTAND Deliverables above.

5.3 Results

Fatality rate has been studied for several scenarios on two reference ships. Detailed results can be found in *Hifi (2012).*

The Sea State is the main parameter influencing the fatality rate (see Figure 6). In severe sea states, the manoeuvrability performance of LSAs to clear off the vessel is predominant.

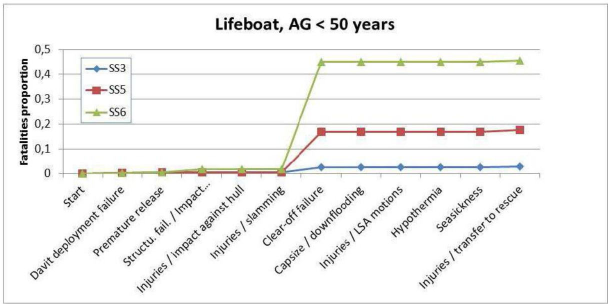


Figure 6: Influence of sea state

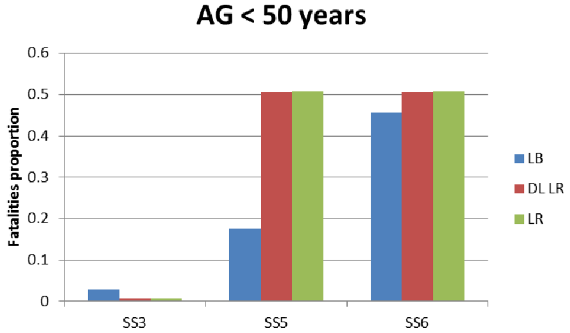


Figure 7: Comparison between LSAs (LB: Davit-lauched Lifeboat, DL LR: Davit-Launched Liferaft, LR: Ladder boarded Life-raft)

6. DECISION MAKING (WP6)

The VulnerabilityLog, or VLog for short, is presented in *Jasionowski (2011)* as a functionality to inform the crew at all times on the instantaneous vulnerability to flooding of the vessel, considering its actual loading conditions, the environmental conditions and the actual watertight integrity architecture. The vulnerability is proposed to be measured in terms of the probability that a vessel might capsize within given time when subject to any feasible flooding scenario.

Models for loss function and likelihood functions have been developed and proposed, and an integrated format of decision making process addressing ship's residual stability, the abandonment and the rescue operations, as well as dominant inherent uncertainties have been proposed, see *Jasionowski (2012a, b) and Hifi (2012)*, as follows:

Step 1 - Order mustering and follow with situation assessment at the first sign of distress

Step 2 - If flooding extent not determinable or escalating then abandon

Step 3 – Else if $\left[\min(0{,}125\cdot H_s,1)\langle F_{cap}(3hrs \mid H_s)\right]$ then abandon

Step 4 - Else stay onboard.

Note! In Step 3 above, the order to abandon the ship is tightly coupled to the significant wave height (H_s) and to the applied models of:

- expected losses in case of abandonment: min(0,125·H_s, 1)

and

- expected losses in case of capsize in 3 hours: F_{cap} (3 hrs|Hs)

On the basis of a decision expected to lead to least expected casualties, Step 3, as given in *Jasionowski (2012c)*, simply suggests to abandon, if the latter value is higher.

Some fundamental uncertainties, described in the reports above concerning the various stochastic capsize models, related to the assessment of the extent of flooding, do not seem resolvable at present according to *Jasionowski (2012c)*. Therefore, and given considerable level of typical ship vulnerability to flooding with possible rapid capsize, it is recommended in the above process that the order to muster is an automatic and immediate crew reaction to first report or a sign that distress occurs. During the mustering time all efforts to assess the extent of flooding must be made, and in case doubts remain as to the scenario, or in case the flooding is escalating, an order to abandon should be given.

In case flooding situation is well established, a quantitative criterion is given to make judgement on the risk balance between decisions of abandonment and staying onboard. Naturally, the above process is susceptible to subjective interpretations as to what constitutes "doubt" or "well established" situation awareness, and these are proposed to remain discretionary judgements of the crew.

Technologies (better sensors, their denser distribution and good maintenance) and procedures for monitoring of all of ship spaces should be, and have been, developed, so that this fundamental uncertainty can be resolved. However the proposed procedure above would seem competent and generic independent of the state of technology, see *Jasionowski (2012c)*.

The process highlights the important decision making elements, which when used in training may allow the crew to better understand importance of their preparedness for handling crises.

Assessment of the likelihood function is proposed to be adopted for any type and size of the vessel by *Jasionowski (2011)*, even though its key validation was performed for RoPax type ships only, as the formulation is based on generic parameters of residual stability, as well as generic assumptions on the impact of the process of floodwater progression ("GZ cut-off at down-flooding points"), with the latter mitigating the mentioned expected uncertainties of situation assessment.

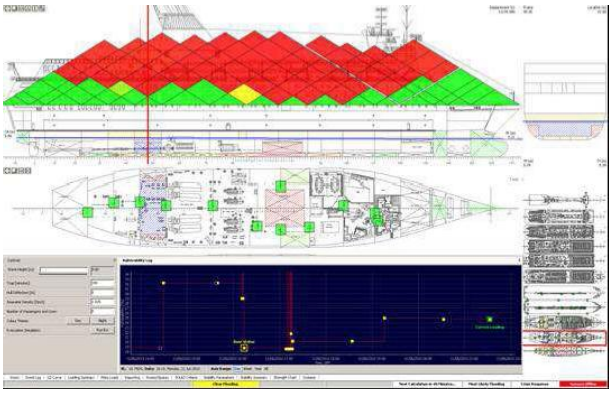


Figure 8: A schematic example of the view on computer screen with a sample information of the functionality VLog as shown by *Jasionowski (2012c)*.

Vulnerability due to open WT doors (between watertight compartments) was shown to be an important issue, to be clearly demonstrated for the crew members. The importance of the subdivision on the damage stability of the ship should be obvious to everyone involved. Floodwater that is allowed to progress freely, via an open WT door, from one compartment to another may in some cases tip over the whole ship. The actions of the crew may have a big impact on the ship's vulnerability and operational risk related to flooding cases. Any functionality and training that can be used to raise the awareness of the crew about flooding risk, and the right actions to minimize the risk can have a notable impact on crew actions. Improvements in crew awareness and in support for decision-making, and training, can be used to promote a safety culture, where the aim is laid on a (continuous) improvement.

7. EFFECTS ON SHIP DESIGN (WP1&7)

Near the end of the project a comprehensive analysis of the obtained results and their effects and applications in the modern cruise ship design was carried out, Routi et al. (2012).

The results of the analysis did not reveal any major observations having significant influence on the general design of cruise vessels, but many of the assumption defined in the SOLAS explanatory notes could be confirmed.

The main focus was laid on the sustainability of non-watertight structures and how this may be used to enhance safety and to consider the physical behavior of the design. Here are the fire doors the main equipment, which – according to the current requirements – are regarded as non-watertight boundaries seriously restricting the flooding. According to the test results typical A-class fire doors are capable of withstanding a water pressure of app. 2.5 m before collapsing. The expected pressure head varies remarkably on different decks which subject to flooding. Based on this feature fire doors should be considered either as collapsing structures or an impermeable boundary, depending on the location. This effect can be used for restricting (or retarding) progressive flooding on the bulkhead deck, but on the tank top level the flooding through fire doors will take place in practice instantaneously.

Cold rooms and dry stores are currently subject to compliance with the same requirements to watertight integrity as fire doors. Considering both the typical location and construction of such rooms and the practice to keep the rooms normally closed, it is reasonable to assume that it may take a considerable time to flood these rooms.

Another important item is the effect of air pressure for cross flooding calculations. Here the obtained results provide the designer a more accurate method to consider and predict the effect of air pressure for the flooding scenario rather than using the 10% rule as proposed in the explanatory notes at the moment. The design of the tank and void spaces arrangement with air ducts and cross flooding ducts can be made in a more flexible way and the available space can be used more effectively.

Although the results do not lead us to the global design changes, some important details for the designer are explored and will influence the designs of cruise ships in the future. In addition, the findings of this project provide more precise input data for time-domain flooding simulations and thus improve the accuracy of the calculations and promote the acceptance of such calculations by the flag administrations.

The design changes can, however, only be applied, if the regulatory bodies consider the results of this project while developing new requirements for subdivision and stability within SOLAS. Some important details should be incorporated in SOLAS and the explanatory notes:

- flooding sequence through fire doors
- instantaneous flooding on tank top through fire doors
- restriction of flooding on bulkhead deck through fire doors
- new formulation for cross-flooding through ducts with restrictive effect of air pressure
- restriction of flooding in cold room area

The lay-out of spaces and the use of watertight doors in daily operation have an important influence on the vulnerability of a modern cruise ship. This may be affected by taking into account the operational needs at an early design stage. It has been shown, that the design of cruise ships can easily consider the operational needs, so that watertight doors are only used as secondary means of escape and need not to be opened during the daily service. These design changes may, however, require solutions and arrangements which lead to a lesser attained index and imply corresponding counter measures to comply with the rules, thus increasing the investment and life-cycle costs of the ships.

The analysis conducted and the experience collected in WP4-6 demonstrate that the loss, which is related to a damage with an extent of significance large enough to allow the progression of flooding in a quantity leading to the capsize of the ship, is a fast process. Thus, as addressed by *Spanos & Papanikolaou (2011, 2012)*, it is an urgent situation for the people onboard to timely evacuate the ship, maybe much more urgent compared to what may have been assumed before. If the time available for the mustering and abandonment of a passenger ship, in the rare severe damage cases that may cause an urgent need for it due to rapid capsize, is less than 30 minutes, as it was in many of the simulated cases, the sufficiency of the existing safety level, with all its components, seem to require careful reappraisal and improvements. An option for a reasonable strategic objective for the passenger ship design may be formulated out of this research, namely to establish even higher survivability requirements (sub-division required indices), so that the ‘non-survival’ cases could be limited to a minimum, and/or to pursue, where possible, even faster evacuation and abandonment procedure.

The question of reducing the vulnerability due to open watertight doors in operation depends strongly on the SOLAS requirements. Only if the regulatory bodies agree on clear design requirements, future ship designs will be improved without economical disadvantages for the operators or shipbuilders.

8. CONCLUSIONS

The output of this research project is notable. It is considered to fill many gaps of information and lack of data to enhance more reliable flooding simulations. The results can be used for assessments of damage stability carried out due to various design purposes and, additionally, in onboard applications. They offer good prospects to improve timely support for designers and operators of passenger ships.

The work of project FLOODSTAND can be assumed to be valuable for the development of safety regulations concerning passenger ships, too. Most of the results can be further refined and will be submitted to the IMO SLF meetings, as already done in some cases. This work need to be done together with the member states.

Many of the results and general conclusions are related to intermediate stage flooding and progressive flooding. This information is presumed to be helpful in the work underway to refine the current intermediate stage flooding guidance. The flooding detection systems for passenger ships has been addressed, too. Information and results from the relevant part of the work could be used to update guidance for sensors and their arrangements, locations, types, etc.

The work in this research project has been carried out concentrating mainly on purely technical issues, therefore often focused on issues being more or less straightforward to be solved. However, the multitude of various interactions between the applied technology, human operators and the environment, should never be totally forgotten. It is assumed and hoped that the achievements and results obtained in project FLOODSTAND will foster better understanding and capabilities to cope with a number of important parts within this huge framework and, especially, in relation to the development of the safety of passenger ships.

9. ACKNOWLEDGEMENT

The research leading to these results has received funding from the European Community's Seventh Framework Program (FP7/2007–2013) under grant agreement no. 218532 (project FLOODSTAND). The financial support is gratefully appreciated.

Although the opinions professed in this paper represent those of the individual authors, the team of which was selected from each WP leader organisation of FLOODSTAND, the paper strives to objectively describe the whole collaborative project.

Acknowledgement is naturally given to all members of the project Consortium and to all members of the Advisory Committee, too.

10. REFERENCES

Note! All the reports (deliverables) of this EU-funded project that are listed below are publicly available via the project webpage at http://floodstand.aalto.fi/Info/public_download.html.

IMO SLF47/INF.6 2004. Large Passenger Ship Safety: Survivability Investigation of Large Passenger Ships, submitted by Finland, 11. June 2004.

IMO Resolution MSC.245(83), 2007. Recommendation on a Standard Method for Evaluating Cross-Flooding Arrangements.

IMO MSC.1/Circ.1291 2008. Guidelines for Flooding Detection Systems on Passenger Ships, 8 December 2008.

IMO SLF54/INF.8/Rev.1 2011. Modelling of leaking and collapsing of closed non-watertight doors, submitted by Finland, 28 October 2011.

IMO SLF54/4 2011. An analysis of the recommendation on a standard method for evaluation of cross-flooding arrangements as presented in resolution MSC.245(83), submitted by Finland, 14 October, 2011.

Hifi, Y. 2012 Report on the method for assigning of uncertainty bounds for methods for M-A-R assessment, FLOODSTAND Deliverable D5.5.

Jakubowski, P., Bieniek, N. (2010). Experiments with leaking and collapsing structures, FLOODSTAND Deliverable D2.1b.

Jalonen, R., Jasionowski, A., Ruponen, P., Mery, N., Papanikolaou, A., Routi, A-L. 2010. FLOODSTAND – Integrated Flooding Control and Standard for Stability and Crises Management, Proceedings of the 11th International Ship Stability Workshop, Wageningen, The Netherlands 21-23.6. 2010, pp. 159-165.

Jasionowski, A. 2011. Decision support for ship flooding crisis management, Ocean Engineering, Vol. 38, pp. 1568-1581.

Jasionowski, A. 2012a. Analytical model of stability deterioration process, FLOODSTAND Deliverable D4.2.

Jasionowski, A. 2012b. Hybrid model of stability deterioration process, FLOODSTAND Deliverable D4.4.

Jasionowski, A. 2012c. Standard for decision making in crises – loss and likelihood functions, FLOODSTAND Deliverable D6.2.

Karlberg, D., Jalonen, R., Ruponen, P. 2011. Sensitivity Analysis for the Input Data in flooding Simulation, FLOODSTAND Deliverable D2.6.

Manderbacka, T., Matusiak, J., Ruponen, P.

2011. Ship Motions Caused by Time-Varying Extra Mass on Board, Proceedings of the 12th International Ship Stability Workshop, Washington D.C., U.S.A. 12-15.6.2011, pp. 263-269.

Maurier, P., Hifi, Y., Corrignan, P. 2011. Report on validation and sensitivity testing of methods for assessing effectiveness of abandonment process, FLOODSTAND Deliverable 5.3.

Maurier, P., Corrignan, P. 2011. Report on validation and sensitivity testing of methods for assessing effectiveness of rescue process, FLOODSTAND Deliverable 5.4.

Nicholas, C., Mery, N., Hifi, Y. 2010. Benchmark data: Introduction to the Mustering, Abandonment and Rescue models", FLOODSTAND Deliverable D5.1.

Penttilä, P., Ruponen, P. 2010. Use of Level Sensors in Breach Estimation for Damaged Ship, Proceedings of the 5th International Conference on Collision and Grounding of Ships ICCGS 2010, Espoo, Finland 14-16.6.2010, pp. 80-87.

Penttilä, P. 2012. Design Guidelines for Placement and Technical Requirements of Flooding Sensors in Passenger Ships, FLOODSTAND Deliverable D3.3.

Rask, I. 2011. Report on physical model experiments with ship model, FLOODSTAND Deliverable D4.1.

Routi, A-L., Luhmann, H., Manderback, T., Seglem, I. 2012. Analysis and Applicability of Alternative Designs, FLOODSTAND Deliverable D1.2.

Ruponen, P., Routi, A.-L. 2011. Guidelines and criteria on leakage occurrence modeling, FLOODSTAND Deliverable D1.2.

Ruponen, P., Queutey, P., Kraskowski, M, Jalonen, R., Guilmineau, E. 2012a. On the calculation of cross-flooding time. Ocean Engineering Vol. 40, 27-39

Ruponen, P., Larmela, M., Pennanen, P. 2012b. Flooding Prediction Onboard a Damaged Ship, accepted to STAB2012.

Spanos, D., Papanikolaou, A. 2011. On the time dependence of survivability of ROPAX ships, Journal of Marine Science and Technology, Published online, DOI: 10.1007/s00773-011-0143-0

Spanos, D., Papanikolaou, A. 2012. Report on the applicability of the standard for design practice, FLOODSTAND Deliverable D7.3.

Stening, M., Järvelä, J., Ruponen, P., Jalonen, R. 2011. Determination of discharge coefficients for a cross-flooding duct. Ocean Engineering Vol. 38, 570-578.

Ypma, E. 2010. Model tests in atmospheric and vacuum conditions, FLOODSTAND Deliverable D2.5b.