COMMITTEE II.1
QUASI-STATIC RESPONSE

COMMITTEE MANDATE

Concern for the quasi-static response of ships and offshore structures, as required for safety and serviceability assessments. Attention shall be given to uncertainty of calculation models for use in reliability methods, and to consider both exact and approximate methods for the determination of stresses appropriate for different acceptance criteria.

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1. DISCUSSION

1.1 Official Discussion by Sang-Rai Cho

1.1.1 Introduction

It is an honour to be invited to serve as an official Discusser of the Committee II-1 report. Firstly, the Discusser wishes to express his sincere appreciation to the Committee Chairman, Professor Jonas Ringsberg, and his Committee members for their extensive review works on the Quasi-Static Response and performing interesting and timely benchmark studies.

Certain changes have been made to the contents of this report from the previous one. “Load modelling” and “Structure modelling and response analysis” have been separated into Chapters 2 and 3, respectively. These chapters form the core of the report, together with Chapter 4: “Uncertainty and reliability analysis”. Reviews on ship and offshore structures are combined in Chapter 6 and concluding remarks are provided for every chapter.

The mandate of this Committee encompasses an extensive field of research topics. Following discussions at the former ISSC congress in 2015, the Committee decided that the report should prioritise and emphasise the most relevant issues during the reporting period. Furthermore, the Discusser also follows the discussion of the former ISSC congress in this report. Only certain topics are discussed in-depth among those touched on by the Committee.

1.1.2 Load modelling

In the current report, the loads applied on ships and offshore structures are divided into two major categories: operational and accidental loads. However, Jones (1991) classified the marine structural impact loadings as follows:

- Mass impact loading: collision, grounding, drop object.
- Repeated dynamic loading: slamming, sloshing, green water, ice load.
- Explosive pressure loading: gas explosion, underwater explosion, air blast.

Jones (1991) categorised slamming, sloshing, green water and ice loading as repeated dynamic loadings. The necessity of research on the cumulative damage owing to repeated slamming loads was also noted in the report of the ISSC Committee V-7 (Cho et al. 2009). Although remarkable progress has been made in marine structural design against impact loadings, the effects of the repetition of impact loadings have not yet attracted significant attention of marine structural engineers and researchers.

The results of repeated lateral mass impact tests on a grillage structure are illustrated in Figure 1 (Truong et al. 2018). It can clearly be observed that the evolution of deflection continues until the 19th impact. However, the deflection increments are continuously reduced, but fail to produce a pseudo-shakedown state. Figure 2 illustrates the variation in the normalised permanent set of a plate against the number of impulsive pressure loadings, which were obtained by means of a rigorous parametric study using nonlinear dynamic finite element analyses (Truong et al. 2017). The general tendency of the deflection evolution is rather similar to that of the mass impacts depicted in Figure 1. Depending on the impulse shapes the deflection evolutions exhibit convergence. A pseudo-shakedown state cannot be achieved for this loading either. Based on the experimental and numerical investigation results provided here it can be concluded that the repetition of mass impacts or impulsive pressure loadings cannot be neglected in the structural design against such impact loadings.

It would be interesting to hear the Committee’s view on the repetition effects of slamming, sloshing, green water and ice loading.
1.1.3 Failure mode interaction

As stated in section 3.2 of the report, the observed failure modes must be quantified to understand the ultimate limit state of a structure and quantify the reserve between the structural capability and load over the structure life. The basic failure modes of all marine structural components have been effectively defined. However, the effects of interactions among the basic failure modes, which may decrease the ultimate strength, have not been fully investigated.

However, for ring-stiffened cylinders under hydrostatic pressure several researchers have investigated the effects of failure mode interactions (FMIs). The basic failure modes of ring-stiffened cylinders are inter-frame buckling, yielding between ring-stiffeners, ring-stiffener tripping and overall buckling. Faulkner (1991) considered the interaction between inter-frame buckling and ring-stiffener tripping to improve the collapse pressure prediction accuracy. Several researchers have investigated the failure interaction between inter-frame buckling and overall buckling. Graham et al. (1994) presented a summary of research on the FMIs performed at Defense Research Agency. Morandi et al. (1994) and Graham (2007) performed numerical investigations on the interaction between inter-frame buckling and overall buckling, while Cho et al. (2017) performed hydrostatic tests on ring-stiffened cylinders. Figure 3 illustrates a collapsed ring-stiffened cylinder model under external hydrostatic pressure owing to the interactive local and overall failure mode.

There has been some progress in considering FMI for ring-stiffened cylinder design. Other types of marine structural elements should be investigated whether FMI needs to be considered to improve their resistance predictions.
1.1.4 Buckling and ultimate strength of stiffened plates

It is well known that the initial shape imperfections of stiffened plates can significantly affect their ultimate strength. As noted in section 3.2.1 of the report, several researchers have investigated the effects of the initial shape imperfections on ultimate strength. The majority of researchers assume the lowest buckling mode of the plate as the shape imperfection form. It is also necessary to assume the form amplitude, and the ultimate strength is strongly dependent on the assumed amplitude. As reported by Antoniou (1980), the actual shapes of newly built plates are sinusoidal, dished, horse-shaped, and multi-wave. The initial imperfection shape can be determined by the plate aspect ratio. Two questions are raised regarding the initial imperfection shapes as follows. Why must we assume a different form of the imperfection shape from the actual one? If we must accept the shape assumption; that is, the lowest buckling mode, what is the appropriate manner in which to determine the amplitude?

1.1.5 Uncertainty and reliability analyses

The Committee categorises the uncertainty into aleatory and epistemic uncertainties. Aleatory uncertainty is a natural randomness of a quantity, such as variability in the strength of materials. In the case of material yield strength, which is one of the most influential parameters for the resistance of structures, another type of uncertainty exists, namely “system uncertainty”. Traditionally, it has been preferable to use the minimum yield strength value, which can be obtained as the fifth percentile. Gaspar and Guedes Soares (2013) presented their hull girder reliability analysis results. They assumed 269 and 348 MPa as the mean yield strengths of normal strength steel and high-strength steel, respectively. Presumably, they obtained these values from the minimum values specified in the class rules: 235 MPa for normal strength steel and 315 MPa for high-strength steel.

Table 1 provides a summary of over 7000 mill test certificates provided by a medium-size shipyard in Korea (Cho et al. 2015). The mean yield strength of A-grade is 312 MPa, while that of AH32-grade is 386 MPa. The mean values provided in Table 1 are significantly higher than those assumed in Gaspar and Guedes Soares (2013). If the reliability analyses were performed again with different yield strength values, the analysis results would be very different. This is one example to spare our efforts for improving reliability prediction.
Table 1: Material properties obtained from mill test certificates (Cho et al. 2015).

<table>
<thead>
<tr>
<th>Material</th>
<th>No. of coupons</th>
<th>Yield strength</th>
<th>Ultimate strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean (MPa)</td>
<td>COV (%)</td>
</tr>
<tr>
<td>A</td>
<td>2323</td>
<td>312</td>
<td>8.5</td>
</tr>
<tr>
<td>B</td>
<td>22</td>
<td>315</td>
<td>5.7</td>
</tr>
<tr>
<td>D</td>
<td>46</td>
<td>315</td>
<td>7.1</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>316</td>
<td>14.4</td>
</tr>
<tr>
<td>AH32</td>
<td>2602</td>
<td>386</td>
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</tr>
<tr>
<td>EH36</td>
<td>41</td>
<td>432</td>
<td>4.6</td>
</tr>
</tbody>
</table>

1.1.6 Development of rules

Since the 13th ISSC held in Trondheim, Norway, reviews on recent developments in structural design guidelines have been included in Committee II-1 reports. These reviews types would be very welcome to researchers in academia who do not perform daily checks on changes in new class rules. In the current report, the latest developments in the rules and software systems are reviewed intensively, and certain new developments are highlighted here.

In the new DNV GL rules, the equivalent design waves (EDWs) concept is introduced to calculate environmental loads. The calculated loads by means of CSR-H are applicable to bulk carriers and oil tankers only. However, DNV GL has constructed EDWs that are applicable for all ship types and sizes. The new DNV GL rules provide three levels of direct calculation methods for single panels and hull girder ultimate strength evaluation, namely closed form methods (CFM), semi-analytical methods (PULS), and nonlinear finite element (FE) analysis.

Research on the MOL Comfort accident prompted certain developments related to container ship design. The IACS addressed the functional requirements for FE analyses of container ships (IACS 2015c) and issued the “Longitudinal Strength Standard of Containerships” (IACS 2015a). Whipping and springing are highly relevant for ultra-large container ships. The Lloyd’s Register 2014 rules include mandatory requirements for the assessment of whipping and springing on global hull girder loads (LR 2014). ABS (2017) published new guidance for springing assessments. Furthermore, DNV GL updated the methods for whipping and springing assessment in their new rules (DNV GL 2016c); note: see the Committee’s report for the references in this paragraph.

1.1.7 Benchmark studies

The Committee performed two interesting benchmark studies that should be commended. The first is an investigation of the discretisation of wave loads and its influence on the longitudinal structural behaviour in direct calculations using global ship models. In recent years, direct calculations have been performed more frequently during the early ship design stages. Therefore, it is necessary to provide a standard procedure of direct calculations. In the report, the following four load cases were selected for comparison:

- Load case (a): forces applied on the nodes at the centreline of all bottom transverses.
- Load case (b): forces applied on the side nodes of all bottom transverses.
- Load case (c): forces applied on all nodes of all bottom transverses.
- Load case (d): forces applied on all bottom nodes.

The study results indicate that the force must be transversely distributed on the bottom shell nodes in the schematisation of wave loads. It was also stated that, regardless of the ship type, the lower limit in the load simplification is represented by load case (c).
Another benchmark study comprises the fluid-structure interaction (FSI) analyses of a stiffened plate subjected to slamming loads. Two different commercial software packages were employed for the FSI analyses: LS-Dyna and Star-CCM+/Abaqus multi-physics co-simulation. Although the pressure levels of the two simulations were similar, the pressure peak shapes differed. The maximum deflections predicted by the two simulations exhibited strong agreement. However, certain differences were apparent in the deflection time histories.

In this report, the results of two different simulations are compared. Obviously, it would be preferable to substantiate the numerical predictions with available test results. Not many test results include the pressure and deflection histories; however, certain data are available in the open literature (Mori 1977).

For the second benchmark study, one of the objectives was to determine the corresponding equivalent static and uniform pressure that results in the same permanent deformation as the FSI analysis. The Discusser believes that this is one of the key tasks that should be performed by the Committee of Quasi-Static Response.

At this juncture, two questions can be raised regarding the structural design for slamming, for instance. As mentioned in section 1.1.2, it appears to the Discusser that the repetition effects should be considered to determine more realistic characteristics of slamming loadings. What is the Committee’s view on this matter? When the ship bow or stern structures are subjected to slamming loadings, which limit state should be considered: the accidental or serviceability limit state?

1.1.8 Closure

In the conclusion to the report, the Committee urges researchers to consider the use of appropriate experimental work to verify simulations. The Discusser fully supports this conclusion. In order to use appropriate experimental work for the verification of numerical simulations, there should be some researchers who perform experiments.

The Committee mentions that time is one of the main drivers during the design stage. Of course, quasi-static approaches are welcomed for cases in which responses are quasi-static. However, even for cases in which the responses are not quasi-static, equivalent quasi-static approaches are also necessary.

The Discusser would like to close by thanking all of the members of Committee II-1 of ISSC 2018 for their contributions and valuable time-sharing.

1.2 Floor and Written Discussions

1.2.1 Robert Sielski – Consultant (U.S.A.)

The committee has reviewed many papers advancing the technology of reliability and uncertainty analysis. However, their review of the development of rules and regulation show no inclusion of reliability-based design. Reliability-based design has been advocated for more than 30 years, yet appears to have found no application in design. Could the committee please comment on why they believe that reliability-based design is not in current use?

1.2.2 Zhaolong Yu – Norwegian University of Science and Technology

Question regarding the second benchmark study and the application of the FSI for the slamming problem, because we have a similar study. This is a very important issue especially in Norway and North Sea. My question is: when you do the LS-Dyna simulation, I see that your mesh size is 100 mm. I think that this is a pretty large mesh size for this kind of FSI simulation. We did similar analysis and we did a convergence study. In this case, we were ranging the mesh size from 5 to 100 mm. In our case we could find convergence for 10 mm.
The solid fluid domain is just a bit larger than the structure, so I was guessing if there are some boundary effects caused by the reflection from the fluid boundary?

The committee recommend an equivalent static slamming pressure for design. Since the slamming is a very complex coupling problem there is a significant hydro-elasto-plastic coupling between the fluid and the structure. I was just wondering if this kind of equivalent static slamming pressure is really working well for this problem.

**1.2.3 Ekaterina Kim – Norwegian University of Science and Technology**

Question regarding section 2.1.3 “Ice Loads”. You have indicated that ice loads can be categorized as “stationary” or “moving”. From fundamental thinking, I believe that all ice loads are moving loads, either the ice is static and the structure is moving through it or the ice field is moving and the structure is static. Following from this, I’d like to ask you if you could make an example of an ice load acting only on a single point of the structure.

**1.2.4 Nicole Ferrari – Fincantieri**

Regarding the second benchmark study, I would like to know if it would be possible to apply the same case study to a more complex structure in order to simulate a more realistic scenario? Not only the structure, but even the applied load/pressure distribution could be more complex.

**1.2.5 Sue Wang – ABS**

In your literature review, have you found other publications that show similar relationship between relative vertical velocity and impact load presented in the slamming load benchmark study?

**1.2.6 Manolis Samuelides – National Technical University of Athens**

Question on first benchmark study: you have applied 4 different load cases. Are there any rules that suggest any of those load cases?

**1.2.7 Guillaume de Hauteclouque – Bureau Veritas**

In your recommendations you say that we should have further look into the load combination factor. What is your opinion about this? What is your opinion about the current practice?

**1.2.8 Sheng Dong – Ocean University of China**

In your final conclusions you talk about the load combination and you say that it must be considered in the design of ship structures. In the second bullet of the Recommendations, you say the following: “Improve methods to account for corrosion and fatigue in assessing structural strength”. What about the interaction of corrosion and fatigue? I think that the interaction model is important but difficult to describe. Can you comment about this?

**1.2.9 Hyunkyoung Shin – University of Ulsan**

Question on drop test (slides from presentation): you show a comparison between the numerical and experimental results from the drop test for the slamming problem. As I see, your data are very smooth, so I think you did a smoothing process of the data that you obtained from the model test. For example, we also did similar test and we have a lot of data in the high frequency region. Moreover, I personally carried out drop test on both wooden wedge and steel wedge. For the wooden edge, I also got this kind of smooth data, but for the steel wedge I obtained more response for the high frequency response region. For example, the second response peak is much larger than the first. Maybe this problem was only related to my test, but what about your test?

**1.2.10 Philippe Rigo – University of Liege**

Question on slide 26 in the committee’s presentation: I have doubts about the load cases “c” and “d” and I would suggest the committee really think about this. In fact, the benchmark study
is only made to apply hull global bending loads. What is happening with load cases “c” and “d” comes from the fact there are some local bending moments that create disturbance of the global analysis. I think that you should exclude these two last load cases. Can you please comment on this?

2. REPLY BY COMMITTEE

2.1 Reply to Official Discusser

2.1.1 Introduction

The Committee would like to thank the official Discusser Professor Sang-Rai Cho for his effort and kind contribution to the assessment of the Committee Report. The Committee appreciates Professor Cho’s (hereafter referred to as the “Discusser”) valuable and inspiring comments which we reply to in the following.

2.1.2 Load modelling

Early work by Zhu and Faulkner elaborated on the pseudo-shakedown state of plates when a structure is subject to dynamic pulses that are repeated in nature. The study indicated that “A rigid perfectly plastic structure would have reached a pseudo-shakedown state, and would not then deform under repetitions of the same dynamic pressure pulse”. This is the same behaviour that Truong et al. (2017) account on their recent work. Jones (2014) also evaluated these effects and outlined that “a plate subjected to identical mass impact loadings does not achieve a pseudo-shakedown state after some inelastic behaviour, except in the special case when small enough loadings can be absorbed due to an increase in the elastic range which is associated with the development of finite displacements, or geometry changes”. The author then goes to account for this small displacement as small kinetic energies being absorbed by the elasticity of the material and introduces a saturation state. Truong et al. (2017) also came up with some similar conclusions for future work in evaluating the effects of “strain hardening and strain-rate hardening on the dynamic response of marine aluminum alloys”. They also discussed the “saturation state” which a single quasi-static pulse can result in permanent deformation state, after which a similar small pulse will not cause further permanent deflection. The authors also outline that further inclusion of fracture damage could be considered.

Overall the effects of repeated impulse loadings on the deformation of structures is a critical area for investigation, specially developing a saturation state load model, plus involving material models and working in conjunction with ISSC Committee III.2 (Fatigue & Fracture) to elucidate on the micro-scale behaviour that can result in macro-scale observable responses. With the increased use of ships in high latitude regions where ice loads are probable, plus slamming and sloshing, deeper understanding of pseudo-shakedown states is needed to address their effect on the design loads of structures and their associated longevity.

2.1.3 Failure mode interaction

In Chapter 3 of the Committee’s report, Chapter 3 “Structural modelling and response analysis” deals with different failure modes in different sections, where load combinations have been considered without separating them in to a separate section. The Committee agrees with the Discusser that load combinations, but also the interaction of failure modes, are important to consider when assessing the failure of a structure. The current Committee recommends the forthcoming Committee to emphasise on these issues during the next mandate period. With regards to ring-stiffened structures specifically, historical development and analysis of this type of structure (typically seen in submarine pressure hulls, specialist subsea equipment housing, or land based industrial equipment e.g. autoclaves), was covered in detail in Dow et al. (2012) in relation to submarines. The Committee apologises for having not included the Discussers paper within the report in order to update this area.
2.1.4 Buckling and ultimate strength of stiffened plates

In structural design and limit state assessment, the structure is predominantly theoretical at the point of analysis. Subsequently the structure may be constructed with no physical test undertaken to verify calculations, whether analytical or by means such as finite element analysis (FEA). This is very true in the design and construction of ship and offshore structures, where the final vessel or platform may essentially be considered a prototype in many instances. It is true that correlation of experimental results with FEA will be much improved if the actual imperfection shape seen in the structure can be replicated, rather than assuming a representative shape. With advances in techniques such as laser scanning, this should be far easier to record and transfer from an existing structure of experimental configuration to computational model; though it is not presently an approach that has been well adopted or presented to date. For design purposes the actual imperfection pattern is not known; therefore, an assumed imperfection pattern, representative of that which will appear in the end structure, is required. This should correlate with the build processes and anticipated failure modes of the structure, such that the model is not overly stiff, nor is overly influenced by the assumed shape that a single failure mode will always dominate. Dominance of failure modes due to imperfections may lead to the calculated failure not being the lowest mode, and an inaccurate understanding of the structural capacity being developed. This ties to the previous comment on the importance of considering interacting failure modes, which may be achieved through appropriate imperfection shape modelling in all components of the structure.

In relation to the second point raised, the amplitude, as noted, is an important part of the assumed imperfection shape. When increasing the imperfection amplitude in a stiffened plate panel under in-plane axial loading, it can be seen how the overall load carrying capacity of the panel decreases. Furthermore, the increase in amplitude can lead to a change in failure mode, for example from a buckling collapse to yielding failure mode, if the amplitude is excessively large. Therefore, incorrect assumptions for amplitude could lead to incorrect assessment of the structural capacity. Previous work has been presented by different authors to quantify the shape and amplitude of imperfections, such as Smith et al. (1991) and Paik et al. (2006, 2009), and may be used to guide on the appropriate amplitude to assume. The analyst should however consider the relevance to their structure, including build processes, which may be much improved from the time or publication.

2.1.5 Uncertainty and reliability analyses

In the Committee’s report, uncertainties are categorized into two types, aleatory and epistemic uncertainties. If there is natural randomness in the strength of materials which belong to the aleatory uncertainty, it can also be considered in the ship reliability analysis.

The Committee agrees with the Discusser that the mean yield strengths of steels in Gaspar and Guedes Soares (2013) are quite different from the values in Table 1 from Cho et al. (2015), and this may lead to different results of structural reliability analysis. It seems that the uncertainty of yield strength used in Gaspar and Guedes Soares (2013) seems to be based on the guidance by DNV. The Committee thinks that it is a good idea to set the uncertainty parameters based on such a guidance when the result of reliability analysis is compared with that of different structures. However, as the Discusser points out, in order to get reasonable and accurate results of structural reliability analysis, it is valuable to use more recent and accurate information of uncertainty parameters which is closer to reality in the present situation.

2.1.6 Development of rules

The Committee appreciates the feedback on this section. We agree that such a section will be very useful, also in the future. As rules for marine structures commonly are based on quasi-static response calculation methods, information on the latest development will be a convenient
supplement to the review of research literature. Also review of software is considered to give a useful input in a review of quasi-static response calculation methods.

2.1.7 Benchmark studies

The Committee appreciates the Discusser’s valuable comments. For a validity of LS-Dyna, a verification of the slamming analysis was made using a 2D wedge drop model described in Aquelet et al. (2006). A 2D wedge drops into free surface water at 5.425 m/s as depicted in Figure 4, where Figure 5 presents the time history of the pressure at a point located 40 mm from the apex. Figure 6 presents the results from the Committee for a penalty factor $k_d = 0.04$. The patterns are quite similar; however, some details are slightly different, e.g., the maximum amplitude, the period of the first peak, and the starting point of the uprising angle. These details of the pressure are dependent on simulation parameters (e.g., the penalty factor, $k_d$), the initial distance between the wedge and the free surface, the self-weight of the wedge, numerical noise filtration, the mesh size of rigid wedge, equations of state and so on) of which the definitions were not defined in Aquelet et al. (2006).

Figure 4: 2D rigid wedge impacting water free surface at 5.425 m/s, from Aquelet et al. (2006).

Figure 5: Pressure history at 40 mm from the apex, from Aquelet et al. (2006).
In the Committee's second benchmark study in section 7.2 of the report, the repetition effects are related with the randomness of irregular wave and the corresponding irregular motion of floater. Thus, the impact pressure has a feature of high nonlinearity and there exists a large variation in the impact force when measured in an experiment in an irregular sea state. However, the determination of design slamming load from the irregular response in a probability way is another topic and it seems to be beyond the scope of the Quasi-Static Response Committee.

Regarding the limit state, it depends on what exceedance probability in long term distribution is applied. If the level of exceedance probability is low (it is the approach of rule regulation), it is used in the scantling of stiffeners on the bow and stern structures and the criteria for serviceability limit state is employed. However, if an extreme impact load calculated from CFD analysis or experiments and nonlinear FEA with large range of impact load is used, the criteria for accidental limit state is adopted.

2.1.8 Closure

The Committee thanks the Discusser for valuable and thoughtful feedback on the Committee's work.

2.2 Reply to Written and Floor Discussions

2.2.1 Robert Sielski – Consultant (U.S.A.)

When the Committee planned its work, from the beginning we decided to make our priority on different topics. Chapter 4 presents a review of literature on reliability and uncertainty analysis. Reliability-based design was not given that much focus by the Committee during this mandate period. In the Committee’s report, there were some examples of current applications in ships and offshore structures such as oil tankers, offshore platforms and FPSOs. Nevertheless, the Committee recommends the next committee to pay more attention to it during the next mandate period. The Committee’s view is that it is a very important topic.

2.2.2 Zhaolong Yu – Norwegian University of Science and Technology

All Committee members that participated in the benchmark study received the same specification regarding e.g. the geometry, boundary conditions, velocity of the block of water, etc. from the member who coordinated it. After that, each participating member created the meshes, fine-tuned their models and parameter settings according their best knowledge and experiences. Convergence analysis was of course part of this process. It resulted in different mesh sizes for LS-Dyna and Star-CCM+/Abaqus models, also because these codes are a bit different; see the committee’s report for more information.

The size of the computational domains was selected very carefully to ensure that the numerical solutions were not affected by any boundary effects. This was of course checked both for LS-Dyna and Star-CCM+/Abaqus.
The Committee compared two commonly used FSI softwares to simulate and analyse this complex load case with a slamming load acting on a stiffened panel structure. The Committee agrees that it is a challenging problem to simulate it in detail. In the early design of deck box structures simplified tools are needed. Thus, the purpose of proposing equivalent static slamming pressure according to DNV (2010) was to pay attention to how the value of $C_p$ is affected by the velocity of the water block if the equation proposed should be used in the early design of similar structures subjected to slamming loads.

2.2.3  **Ekaterina Kim – Norwegian University of Science and Technology**

The section of the Committee report on ice loads presents a brief overview of recent examples in the literature how ice loads on marine structures are applied. The reference by Kim and Quinton (2016) presents a study where modelling of the ice load as either stationary or moving (sliding along a structure) were compared with regards to the structure’s response for a case with an elastic structure. The study was considered relevant from a fundamental perspective in the early design of marine structures, to pay attention to how researchers and engineers apply ice loads in different ways, maybe without reflecting on how realistic they are. The authors emphasize that the study case was for an elastic plate and if the structure is elastic-plastic, realistic load cases must be considered. For a ship moving in ice, the moving (sliding) ice load case is considered more realistic. An example of a stationary load would in this case be a situation when an ice object is moving/hitting the structure in a single point without sliding along the structure. It could be an offshore structure installed at a fixed location.

2.2.4  **Nicole Ferrari – Fincantieri**

The simulation software used in the second benchmark study can be applied to simulate and analyse similar cases with more complex structures, load situations (e.g. rise angle), boundary conditions, etc. The Committee leaves for the next committee to decide whether this could be of value to study during the next mandate period in a new benchmark study.

2.2.5  **Suqin Wang – ABS**

The Committee wanted to investigate how the velocity of the water impact affected the response of the panel structure in a parametric study. Hence, a number of velocities were chosen more arbitrarily from low to high levels. The Committee’s work has continued after the report was written where additional simulations with more velocities have been carried out. The new results and findings will be published in a new journal publication.

2.2.6  **Manolis Samuelides – National Technical University of Athens**

Different rules give different recommendations and options how to apply loads in direct load analysis using global finite element models. The Committee’s benchmark study on this topic aimed to demonstrate that there is a need to align and recommend how loads should be applied in this type of analysis, as well as how simplified methods that may be used in early design may influence the accuracy of results. Four load cases were defined based on the experience and knowledge in the Committee how researchers and engineers normally do. One passenger and one cargo vessel were chosen as case study vessels together with the Lloyd Register Structural Design Assessment rules (LR 2017); see also the Lloyd Register rules LR (2004) and LR (2014) in the Committee’s report. The results show that the structural response of the two vessels are different sensitive to how the loads are applied. The Committee’s view is that more work is needed in order to draw general conclusions, but highlights to designers that an appropriate loading condition is required to avoid inaccuracies in results.

2.2.7  **Guillaume de Hauteclocque – Bureau Veritas**

The Committee wrote two sections in the report where load combinations and factors, and failure mode interaction are reviewed and discussed. The Committee’s view and recommendation to the next Committee is to pay more attention to these topics and try to summarize what is the
current practice and the need for more research. This was also recommended by the Official Discusser.

2.2.8  Sheng Dong – Ocean University of China

Load combinations and failure mode interaction are important topics that the Committee recommends the next Committee to study in more depth. With regards to aged marine structures, corrosion and fatigue play an important role in the failure mode analysis. Which load combinations that may trigger new failure modes in aged structures in contrast to what was expected in the initial design of new structures need to be studied further. This subject may require that the Committee cooperates more with other ISSC Committees in order to identify good models, practices and analysis procedures.

2.2.9  Hyunkyoung Shin – University of Ulsan

The results the Committee presented from the wedge drop test were from numerical simulations where the results have been smoothed. This is the reason to the smooth results in contrast to what you can expect from results plotted from measurements. Depending on the stiffness of the wedge you may get one or more peaks, and their relative magnitude will also be different.

2.2.10  Philippe Rigo – University of Liege

The Committee appreciates the good comment. This is discussed in the Committee’s report, also in relation to the ship structures that were analysed. Local bending and secondary bending effects are discussed which are more pronounced for one of the case study ship’s structures. The Committee has also presented an extended description and discussion of the benchmark study and its results in Sidari et al. (2018).

REFERENCES


