FIRST EXPERIENCES WITH COMMON STRUCTURAL RULES FOR BULK CARRIERS

M W Nieuwenhuijs, J F Segretain, P Baumans, Bureau Veritas, France

SUMMARY

The IACS common structural rules for bulk carriers have entered into force at the 1st of April 2006. The present paper will present a summary of the technical background of the new rules.

The main innovations of the rules are emphasised:

- Corrosion additions corresponding to 95% of measured corrosion losses after 25 years of service
- Ultimate limit state of the hull girder in intact and damaged conditions in order to minimise the risk of the ship breaking her back at sea
- Concept of a minimum safe domain of loading conditions imposed by classification
- Accidental limit state with flooding of each individual cargo hold and failure of one single side-shell stiffener
- Fatigue life analysis based on 25 years of navigation in North Atlantic environment

In a second part the paper describes the experience gained using the CSR for Bulk Carriers for several projects. A comparison will be made between the different weight consequences according to different rule issues (BV rules, BV rules URS 25 compliant, CSR for Bulk Carriers). This will be done by highlighting three studies as well as looking at the results of the ramification studies performed within the JBP project.

KEYWORDS: Bulk Carrier, Common Structural Rules, IACS

1. INTRODUCTION

At the time of writing this paper, April/May 2006 we can see the first ships being ordered under the new common structural rules which entered into force at the 1st of April 2006. The intention of this is to update the reader on the developments surrounding these new rules and the consequences this will have on the scantlings of new bulk carriers. Considering the need to introduce the project correctly and in order to well describe the developments since October 2005 we have decided to include some of the elements of a paper earlier presented [1] in a very abbreviated way. This is done in chapter 2 and 3. Chapter 4 describes the major changes between the second draft and the final version. Chapter 5 contains the main body of this paper and describes two studies on the weight effects of the CSR rules, next to a the scantling results of a third project as well as the results of the ramification study. Chapter 6 gives some practical comments now that the rules have been introduced.

2. BACKGROUND

2.1 DAMAGE DATA

Two sources of statistical information on bulker losses, the International Collaborative FSA Study lead by the United Kingdom and Intercargo casualty reports, have been used. From the International Collaborative FSA Study lead by the United Kingdom figure 1 shows the frequency of incidents per ship. This figure explains the focus of the measurements taken on the side shell.

![Figure 1: Frequency of incident per BC Class](image-url)
Another way to present data on bulk carrier safety can be found in the Intercargo Bulk Carrier Casualty Reports. Intercargo considers all reports of incidents which appear in the press relating to total losses of bulk carriers over 10,000 dwt. They show 170 casualties from 1990 to 2004. 53 cases involve shell plate failure. The group of navigational errors, stranding and groundings, 56 cases, includes collisions and dragging anchor. Fire and explosion combines both engine room fires and cargo explosions. Flooding also combines both engine room flooding and cargo hold flooding. An overview of the data is given in figure 2. An encouraging trend can be seen in the reduction in the number of ships lost. Another positive trend is that shell plate failure gets less frequent as the cause for total loss.

![Figure 2: No. of total losses and their primary cause per year](image)

2.2 RULE CHANGES

It has not been our intention to explain the extent of each individual rule modification, this explanation can be found in [1], however we wanted to remind the number of rule changes seen over the last years.

2.2 (a) IACS ‘97

Based on the data presented above, IACS decided that enhancement of the safety of bulk carriers had to follow these priorities:
- Strengthen the side shell in order to avoid water ingress
- Avoid progressive flooding of more than one hold
- Alert the crew of a flooding occurrence at a very early stage

These priorities being established, and after the implementation of the enhanced survey program for tankers and bulk carriers in mid 1993, several unified requirements were introduced in 1997. For new ships URS 12, 17, 18 & 20, for existing ships URS 19 & 22.

2.2 (b) IMO, SOLAS chapter XII

At the 1997 SOLAS conference held at the IMO a new chapter was adopted: Chapter XII, Additional Safety Measures for Bulk Carriers. It contained both regulations for new designs and retrospective regulations for existing designs.

2.2 (c) IACS URS 25

URS 25 was introduced in June 2002 following an IACS/industry discussion ignited by a paper put forward by the Hong Kong Ship Owners Association in which they expressed their concerns about design flaws in existing bulk carriers. The loading conditions presented in the loading manual and for which the ship was approved in many cases did not give the owner the ability to use the full potential of his ship.
IACS put together a specialist team to investigate these concerns. They found that a standard set of loading conditions should be prescribed and an inclusive approach was taken to drafting the new requirements which were to become URS 25. Owners and terminal operators were asked to provide their experience and input into the first draft. Applying URS 25 results in a steel weight increase of 5-7%. Thanks to the transparent process of rule making this increase in steel weight has been well accepted by the industry.

2.2 (d) IMO & IACS further measures

The focus on bulkers also led to a number of other changes, which were published as URS 21, 26, 27, 28, 31 and UIISC 179-180, a unified interpretation of SOLAS chapter XII reg 12-13.

Also IMO has continued to issue new regulation. Such as:
- Water ingress alarms and availability of pumping
- Intact stability loading instrument
- Permanent means of access
- Mandatory free fall life boats

And off course reg.14 of chapter XII to enter into force after the 1st of july 2006 which prohibits alternate loading for Bulk Carriers older ten 10 years which do not comply with the requirements to with stand flooding of any one cargohold

2.2 (e) IACS CSR for Bulk Carriers

In June 2003 the IACS council responded to initiatives at IMO and industry and decided to develop a set of common Rules and procedures for the determination of the structural scantlings for oil tankers and bulk carriers. At the 1st of April these rules entered into force. They encompass all the changes and updates above, and also provide a harmonised structural approach across all classification societies.

3. JOINT BULKER PROJECT RULES

3.1 OBJECTIVES AND PRINCIPLES

The Joint Bulker Project Rules are applicable to single side skin and double side skin bulk carriers of a length greater then 90m. All relevant requirements influencing the structural design including SOLAS, Load line and IACS have been incorporated. The project is based on the following objectives:

- To eliminate competition between class societies on scantlings
- To embrace the intentions of the anticipated IMO requirements for Goal-based standards for new buildings
- To ensure that a ship meeting these new Rules will be recognised by industry as being safe, robust and fit for purpose at least as would have been required by any of the existing rules
- To employ the combined experience of all class societies to develop an agreed set of Rules
- To reduce the costs associated with the use of the present ten different sets of rules

3.2 MAIN PROVISIONS

3.2 (a) Net scantling approach

The net scantling approach sets out to determine and verify the minimum hull scantlings that are to be maintained from the new building stage throughout the ship’s design life to satisfy the structural strength requirements. It clearly separates the net thickness from the thickness added for corrosion that is likely to occur during the ship in operation phase.

In order to introduce this net scantling approach to the hull structural rules, at first, we have to have an accurate grasp of the real thickness diminution in operation. For this, corrosion processes from occurrence through propagation were investigated on extensive thickness measurement data, and a corrosion process model was developed based on probabilistic theory, thus estimating the thickness diminution of structural members. Based on this, a guideline on corrosion addition for bulk carriers and tankers was developed and was submitted to the IACS Working party on strength (WP/S). The philosophy of net scantling approach and the corrosion addition values are adopted in the IACS Common structural rules for bulk carriers and tankers.
The corrosion addition was determined by the following procedure (details can be found in the technical paper published in ClassNK Technical Bulletin, Vol.21, 2003, pp 55-71).

1. Gather about 600,000 thickness measurement data sampled from single hull tankers and single side skin bulk carriers of age 5 to 27 years.

2. Select the thickness measurement data of single hull tankers complying with MARPOL 73/78 Convention and with no coating of structural members in cargo oil tanks and of bulk carriers with coated structural members in cargo holds required by the existing IACS UR.

3. Develop a corrosion propagation model to simulate the realistic corrosion phenomenon based on probabilistic theory and identify the necessary parameters for each structural member using the thickness measurement data.

4. Estimate the corrosion diminution at the cumulative probability of 95% for 25 years using the corrosion propagation model.

5. Sort out the corrosive environment to which each structural member is exposed and calculate the amount of corrosion of each corrosive environment using the estimated corrosion diminution of each structural member.

6. Corrosion addition is determined based on the environment to which each structural member is exposed.

In the real corrosion phenomena, scatter of thickness diminution depends on the maintenance condition of the individual ship rather than the thickness measurement of each structural member as shown in Figure 3.

![Figure 3: Statistical analysis of thickness measurement data of structural members of tankers](image)

3.2 (b) Sea induced loads

Wave loads for unrestricted service assume that the ship navigates in the North Atlantic all the year round. The rules are based on these loads and a design life of 25 years, in accordance with the draft IMO Goal Based Standards.

The CSR for Bulk Carriers use the equivalent wave concept. Experience shows that this concept works well in practice and is well adapted to the loading of a finite element model of the ship. It is clearly defined and understood by both hydrodynamics and structural engineers. The scope of this simple loading model is sufficiently general to be applied to local scantling calculations as well as direct loading of a finite element model of a complete ship at sea.

Design load cases are derived from results of the equivalent wave approach as summarised below:

- For each equivalent wave (i.e. for each wave maximising a specific load parameter) the values of the other parameters induced by that wave are calculated.
- The value of each load parameter for the equivalent wave is expressed as a fraction of its long-term value, so that, for each wave, a combination is obtained in which the maximized parameter appeared with a factor equal to 1.0 and the other with lower combination values.
- Each combination identifies a load case.
- Analyzing the load cases so obtained for all the ships considered, it is possible to identify some recurrences in the combinations between the load parameters. Finally, the design load cases are identified.

This process allows identification of four basic load cases.
3.2 (c) Limit states

The serviceability limit state, which concerns normal use, includes:

- local damage which may reduce the working life of the structure or affect the efficiency or appearance of structural members;
- unacceptable deformations, which affect the efficient use and appearance of structural members or the functioning of equipment.

The ultimate limit state, which corresponds to the maximum load-carrying capacity, or in some cases, the maximum applicable strain or deformation, includes:

- attainment of the maximum resistance capacity of sections, members or connections by rupture or excessive deformations;
- instability of the whole structure or part of it.

The fatigue limit state relates to the possibility of failure due to cyclic loads.

The accidental limit state in flooded condition, which is set such that flooding in any one compartment does not progress to other compartments, includes:

- the maximum load-carrying capacity of the hull girder
- the maximum load-carrying capacity of double bottom structure
- the maximum load-carrying capacity of bulkhead structure

In addition, for BC-A and BC-B ships, there is a special accidental limit state, which is set such that single failure of one structural stiffening member in the cargo area does not lead to immediate consequential failure of other structural items, based on the maximum load-carrying capacity of the entire stiffened panels.

3.2 (d) Accepted calculations procedures

Three kinds of calculations are to be performed to study the strength of the primary members:

- A global finite element analysis to assess the strength of the cargo holds structure
- Refined mesh finite analyses in areas of high stress concentration
- A fatigue analysis of structural details

The finite element analysis procedures currently used in the industry, both the direct method and the superposition method with can be used for that purpose. Requirements for both types of analyses are included in the CSR for Bulk Carriers.

3.2 (e) Coating

Performance standards for coatings of ballast tanks and void spaces will be incorporated by IMO into the existing SOLAS Regulation II-1/3-2 concerning corrosion prevention. These new IMO requirements will also be incorporated as part of the Common Structural Rules for both Tankers and Bulk carriers.

4. CHANGES BETWEEN THE SECOND DRAFT AND FINAL VERSION

The second draft was issued on the 8th of April 2005. The final version takes into consideration the large number of comments received from the industry between April and September 2005, as well as the results of the checking calculations done on existing designs, review of damage cases and the comments of Technical Committees of IACS members. The main changes are explained hereunder.

4.1 CORROSION ALLOWANCE

First the harmonisation work between JTP and JBP has resulted in modified rounding formulae. In the second draft the formula for $t_{\text{gross}}$ was:

$$t_{\text{gross\_required}} = \text{Roundup}_{0.5}(t_{\text{net\_required}} + t_c)$$

The definition of the corrosion addition for new building assessment is now:

$$t_c = \text{Roundup}_{0.5}(t_{c1} + t_{c2} + 0.5)$$

$T_{\text{net\_required}}$ is rounded to the nearest half mm. The effect on the scantlings is negligible.
The scantlings have however been influenced by the changes in the individual corrosion margins. In table 1 the changes are indicated. The Corrosion diminution of structural members in the cargo hold depends on the loaded cargoes. Generally cargoes such as iron ore and coal show large corrosion diminutions. In general these cargoes are more transported by panamax and capsize bulk carriers.

The corrosion values for the cargohold area were taken from mean estimated values. As the number of thickness measurement data of the hold frames was quite larger then that of the transverse bulkhead the corrosion values for the transverse bulkhead were lower then the value of the statistics. Furthermore the UGS pointed out that the wind & water strakes, which are located between the ballast load water line and the full water line may suffer large loss of thickness due to contact damage of berthing.

<table>
<thead>
<tr>
<th>Table 1: Corrosion Allowances</th>
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<tbody>
<tr>
<td>Compartment Type</td>
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<tr>
<td></td>
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<tr>
<td>Ballast water tank (2)</td>
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<tr>
<td>Dry bulk cargo hold (1)</td>
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<tr>
<td>Exposed to atmosphere</td>
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<tr>
<td>Exposed to sea water (1)</td>
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<tr>
<td>Fuel oil tanks and lubricating oil tanks (6)</td>
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<tr>
<td>Fresh water tanks</td>
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<tr>
<td>Void spaces (6)</td>
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<tr>
<td>Dry spaces</td>
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<td></td>
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<tr>
<td>Other compartments than above</td>
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</tbody>
</table>

4.2 RENEWAL THICKNESS

During the in-service life the normal thickness measurements will be taken as was already the case with the earlier rules. Figure 4 indicates how the renewal thickness will be determined.
Figure 4: Renewal Thickness

Compared with the 2nd draft it is now possible to use the 0.5 mm reserve additionally before plate renewal when either at each annual survey new thickness measurements were taken or when a protective coating is applied and maintained.

4.3 COMPLIANCE WITH SOLAS XII/6.5.3

The new solas chapter XII which will come into force as per the first of July 2006 (construction date) has an additional requirement with respect to damages of stiffeners surrounding the cargo hold. The exact wording is:

*The structure of cargo areas shall be of such that single failure of one stiffening structural member will not lead to immediate consequential failure of other structural items potentially leading to the collapse of the entire stiffened panels.*

Within IACS URS 12 rev. 4 has been under discussion from mid-2002 to beginning of 2004. The results of that discussion, IACS working group ISR ISWG 1/4 and SOLAS XII/6.5.3 have been incorporated in CSR for Bulk Carriers. The objective was initially to increase the strength of the side shell structure (side frames, but also brackets and longitudinals supporting these brackets). Moving on, the discussion focussed on how to prevent the domino effect of side frames collapsing.

**PRINCIPLES :**

- Local deformation of about 20 mm imposed to one stiffener of the structure adjacent to cargo hold before checking ultimate strength of the stiffened panel under 80% of wave-induced loads (global moments + pressure)
- If the damage is a crack or welding damage, ensure that brittle fracture possibility is avoided

**CLASS REQUIREMENTS :**

- Avoid to perform a specific calculation with 0.8 dynamic loads for each individual ship
- Require safety factor of 1.15 for the ultimate strength calculation of stiffened panels of cargo holds (Ch6 Sec3) covering point 2 here above
- Request grade D/DH for lower brackets of side shell frames (Ch3, Sec1)

4.4 BOUNDARY CONDITIONS OF FEM

Unification of FEM models & boundary conditions has been arranged.

- Direct and superimposition methods both use a three holds model and common boundary conditions in order to obtain same scantlings
- Balancing procedures for both bending moment and shear force are more detailed
- Balancing in shear force with direct method only
- Self-weight of structure is explicitly introduced (Sec 1)

The allowable stress for fine mesh analysis has been described in greater details. Next to that the buckling requirements for DSA have been modified in Ch 6 Sec 3 and an how-to procedure has been introduced in App 2

4.5 TORSION LOADS & HATCH CORNER

The method for calculation of nominal and hot spot stress range in hatch corners induced by torsional moment has been modified to better reflect the results obtained by using complete ship models of the bulk carrier structure. The consequence is that the profiles of hatch corners in certain cases, in the middle part of the ship, may have to be changed from circular to elliptic.
5. CONSEQUENCES FOR SCANTLINGS

Ramification studies were conducted in order to investigate how JBP CSR (Joint Bulker Project, Common Structural Rules), that is, rule sets of corrosion addition, design loads, load combinations, loading conditions, strength analyses and criteria, finally affect the scantlings of actual ships. The ramification studies were carried out on DSS (double side skin) bulk carriers and SSS (single side skin) bulk carriers according to the second draft CSR for Bulk Carriers (released in April 2005). Required scantlings were determined from local scantling calculations, global strength FE analysis, ultimate hull girder strength check and fatigue strength calculations, and the required total steel weight was compared with the light ship weight to present the impact of the JBP draft rules on the actual scantlings.

We will highlight the results of three projects and conclude with the overview of the results of the full ramification study.

5.1 PANAMAX2

Three cross-sections corresponding to three different holds are calculated. For each cross-section, hull girder strength and local scantling are calculated according to all CSR for Bulk Carriers scantling criteria. All structural members of cargo holds 4, 3 and 6 are calculated. They correspond to the ballast hold, a heavy bulk hold (loaded in alternate condition) and a light bulk hold (empty in alternate condition).

Calculations are carried out with the 2D Mars program version 1.9a.

The structural analysis is carried out for two holds:

- The Cargo Hold No.3
- The Ballast Hold No.4

In order to study these cargo holds, two 3D FEM analyses based on 3-cargo hold models have been carried out for the loading conditions defined in CSR for Bulk Carriers.

The FEM program is the New Version of VeristarHull with NX Nastran solver, see figure 5.

For the assessment of weight increase due to CSR for Bulk Carriers 2nd draft, an improvement is made on all structural members according to the CSR for Bulk Carriers. The improvement consists in increasing the scantling of structural members that didn’t comply with the rule criteria for both 2D calculations (Mars calculations) and 3D calculations (FEM calculations).

5.1 (a) Strakes

Regarding strake thickness results, it is necessary to check and compare all structural members results for both kinds of calculations. Four scenarios may occur:

1/ the strake thickness complies with rule formulae but not with FEM criteria: the required thickness is given by FEM calculations criteria.

2/ the strake thickness complies with FEM criteria but not with rule formulae: the required thickness is given by Mars calculations criteria.
3/ the strake thickness doesn’t comply with both calculations: thickness is increased until complying with both calculations criteria.
4/ the strake thickness complies with both calculations criteria: nothing is changed.

5.1 (b) Longitudinal stiffeners

Regarding longitudinal stiffeners, only Mars results are taken into account. Indeed, longitudinal stiffeners are not checked in FEM.

Table 2 shows, for the ballast hold and for the heavy bulk hold, the weight increase for each structural member as well as the type of calculation (2D or 3D) that gives the weight increase.

Table 2: Weight increase

<table>
<thead>
<tr>
<th>Structural Member</th>
<th>Ballast hold</th>
<th>Heavy bulk hold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom</td>
<td>23.10 (Mars + FEM)</td>
<td>22.65 (Mars + FEM)</td>
</tr>
<tr>
<td>Blige</td>
<td>3.79 (Mars)</td>
<td>3.62 (Mars)</td>
</tr>
<tr>
<td>Side shell</td>
<td>3.02 (Mars)</td>
<td>3.02 (Mars)</td>
</tr>
<tr>
<td>Deck</td>
<td>2.81 (FEM)</td>
<td>3.41 (FEM)</td>
</tr>
<tr>
<td>Upper wing tank bulkhead</td>
<td>8.99 (Mars + FEM)</td>
<td>2.95 (FEM)</td>
</tr>
<tr>
<td>Hopper tank bulkhead</td>
<td>2.87 (Mars + FEM)</td>
<td>6.83 (Mars + FEM)</td>
</tr>
<tr>
<td>Inner bottom</td>
<td>4.08 (Mars)</td>
<td>4.08 (Mars)</td>
</tr>
<tr>
<td>Longitudinal girders</td>
<td>9.58 (FEM)</td>
<td>4.32 (FEM)</td>
</tr>
<tr>
<td>Transv structural members</td>
<td>14.74 (FEM + Mars for transv frames)</td>
<td>9.72 (FEM + Mars for transv frames)</td>
</tr>
<tr>
<td>Longitudinal stiffeners</td>
<td>6.53 (Mars)</td>
<td>7.78 (Mars)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>79.50</strong></td>
<td><strong>68.37</strong></td>
</tr>
</tbody>
</table>

5.1 (c) Transverse Bulkheads

Transverse bulkheads are not calculated with FEM. They are calculated with the rules formulae, for both intact and flooded conditions (URS18) as follow:
- Plating thickness of corrugations is calculated in intact condition
- Plating thickness, bending capacity and shear capacity are calculated in flooded condition.

5.2 CAPESIZE BV1

All structural members of cargo holds 4, 5 and 6 are calculated. They respectively correspond to the ballast hold, a heavy bulk hold (loaded in alternate condition) and a light bulk hold. The results are gross scantling results, based on Mars Version 1.9a. No FEM analyses has been made for this design.

5.2 (a) Plating

The strakes in figure 6 are calculated in the three holds for all JBP scantling criteria: yielding, buckling and minimum thickness. The ratios between rules values and as-built values are given for each hold in the following diagrams. A ratio higher than one, means that the concerned plating doesn’t comply with a particular criterion.
Figure 6: Calculated strakes

Plating criteria, ballast hold

- buckling ratio
- yielding ratio
- minimum thickness ratio

<table>
<thead>
<tr>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
<th>T6</th>
<th>T7</th>
<th>T8</th>
<th>T9</th>
<th>T10</th>
<th>T11</th>
<th>T12</th>
<th>T13</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6</td>
<td>0.8</td>
<td>0.2</td>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>1.2</td>
<td>0.8</td>
<td>0.6</td>
<td>0.4</td>
<td>0.2</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Yielding is the most severe criteria for plating located in the bottom area. For the heavy bulk hold (loaded in alternate condition), buckling is important for plating located around top side tank and particularly for top side tank plating in way of cargo hold.

5.2 (b) Longitudinal stiffeners

The stiffeners in figure 7 are calculated in the three holds for all JBP scantling criteria: check of section modulus, shear area, web minimum thickness, torsional and lateral buckling in. Fatigue is treated separately. The ratios between rules values and as-built values are given for each hold in the following diagrams. A ratio higher than one, means that the concerned stiffener doesn’t comply with a particular criterion.
Figure 7: Calculated longitudinals

Stiffeners scantling criteria, ballast hold

- ratio W yielding
- ratio tweb mini
- ratio Ashear yielding
- ratio torsional buckling
- ratio lateral buckling
The stiffeners located on top side tank plating in way of cargo hold don’t comply with lateral buckling criterion. Regarding the yielding criteria, the results depend on the hold section. For the ballast hold section, stiffeners located on bottom, inner hull and top side tank plating don’t comply with the criteria. For the heavy bulk hold, stiffeners located on top side tank plating and on the bilge area (hopper tank, bottom and side shell near the bilge) don’t comply with the criteria. For the light bulk hold, stiffeners located on bottom, inner hull and in the bilge area don’t comply with the criteria as well.

5.2 (c)  Fatigue

For each of the three cross-sections, fatigue is displayed for all stiffener connections in term of lifetime in years. Fatigue is calculated in way of an ordinary frame located in the middle of the concerned hold.
Connection details chosen for the fatigue calculations correspond to details 1 and 2 in CSR for Bulk Carriers, Ch8 Sec4 Table1. These details are respectively represented in the pictures below.

![Fatigue details](image1)

*Figure 8: Fatigue details*

The connections are non-watertight. Fatigue calculations are carried out at point “a”, the most critical point, where the stress concentration factors values are: $K_{gh}=1.1$ and $K_{gl}=1.65$ for detail 1 and $K_{gh}=1.05$ and $K_{gl}=1.5$ for detail 2.

![Ballast Hold](image2)

*Figure 9: Ballast Hold*

![Heavy Bulk Hold](image3)

*Figure 10: Heavy Bulk Hold*
The fatigue calculation results are conservative on bottom connections. Low lifetime also is predicted for the side shell connections around scantling draft.

5.2 (c) Transverse Bulkheads

The transverse bulkheads of the Capesize design are corrugated watertight transverse bulkheads. Only corrugations are calculated. They are calculated for both intact and flooded conditions (URS18) as follow:

- Plating thickness of corrugations is calculated in intact condition
- Plating thickness, bending capacity and shear capacity are calculated in flooded condition.

Two typical transverse bulkheads are calculated: one located between the ballast hold (hold 4) and a heavy bulk hold (hold 3), and the second one located between a heavy bulk hold (hold 5) and a light bulk hold (hold 6).

BETWEEN BALLAST HOLD AND HEAVY BULK HOLD

The corrugation plating calculated is displayed in the figure below; results are given (in gross scantling), in the following table.

<table>
<thead>
<tr>
<th></th>
<th>As-built</th>
<th>Complies with following criteria</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Intact</td>
</tr>
<tr>
<td>t1</td>
<td>22.5</td>
<td>No, 27 required</td>
</tr>
</tbody>
</table>

The corrugations comply with bending and shear capacities criteria under flooding condition.
BETWEEN HEAVY BULK HOLD AND LIGHT BULK HOLD

The corrugation plating calculated is displayed in the figure below; results are given (in gross scantling), in the following table.

<table>
<thead>
<tr>
<th>t1</th>
<th>As-built</th>
<th>Complies with following criteria</th>
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|     | 18.5     | Yes                              |
|     |          | No (on the edge), 19 required    |

The corrugations comply with shear capacity criteria under flooding condition. However, they don’t comply with bending capacity. The value of the required modulus under flooding condition is just above the “as-built” section modulus (calculated according to URS18).

5.2 (c) Weight impact

For the assessment of weight increase due to CSR for Bulk Carriers 2nd draft, an improvement was made on all structural members located on the different cross-sections and transverse bulkheads, according to the CSR for Bulk Carriers. The improvement consisted in increasing the scantling of structural members that didn’t comply with the rule criteria (excepted fatigue criterion). The results of the cross-section calculations, apply on each hold length. Results of such assessment are given in table 3 for each typical hold, and for the entire ship. The results of increase of weight are compared to the lightship weight.

Table 3: Weight impact

<table>
<thead>
<tr>
<th>Ballast hold</th>
<th>as-built transverse section (m²)</th>
<th>optimised transverse section (m²)</th>
<th>ratio added weight/lightship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strakes</td>
<td>5.333698</td>
<td>5.420494</td>
<td>0.0007</td>
</tr>
<tr>
<td>Longitudinals</td>
<td>1.630533</td>
<td>1.690242</td>
<td>0.0005</td>
</tr>
<tr>
<td>Total ballast hold</td>
<td></td>
<td></td>
<td>0.0012</td>
</tr>
<tr>
<td>Heavy bulk hold (loaded in alternate condition)</td>
<td>5.217185</td>
<td>5.297056</td>
<td>0.0007</td>
</tr>
<tr>
<td>Strakes</td>
<td>1.875023</td>
<td>1.755154</td>
<td>0.0007</td>
</tr>
<tr>
<td>Total heavy bulk hold</td>
<td></td>
<td></td>
<td>0.0013</td>
</tr>
<tr>
<td>Light bulk hold (loaded only in homogeneous condition)</td>
<td>5.229797</td>
<td>5.291336</td>
<td>0.0005</td>
</tr>
<tr>
<td>Strakes</td>
<td>1.592813</td>
<td>1.666252</td>
<td>0.0006</td>
</tr>
<tr>
<td>Total light bulk hold</td>
<td></td>
<td></td>
<td>0.0011</td>
</tr>
<tr>
<td>Transverse bkd heavy/light</td>
<td></td>
<td></td>
<td>0.0012</td>
</tr>
<tr>
<td>Transverse bkd heavy/ball</td>
<td></td>
<td></td>
<td>0.0001</td>
</tr>
<tr>
<td>Total ship</td>
<td></td>
<td></td>
<td>0.0186</td>
</tr>
</tbody>
</table>

This table shows that the weight impact due to the application of CSR for Bulk Carriers 2nd draft, on this Capesize design, is an increase of weight around 1.8 – 1.9%.

5.3 CAPESIZE BV2

For this capsize both MARS and Veristar Hull calculation were performed. On overview of the results is given in figures 12 & 13.
5.4 RAMIFICATION STUDY

The IACS ramification studies concluded:
- JBP CSR requires a slight increase in steel weight in general.
- The steel weight increase of a UR S25 compliant ship is relatively small; 2.7 to 3.7%.
The steel weight of ships which are not UR S25 compliant increases by 3 to 8% or 6% on average, depending on the ship size/shipyard/class, etc.

For ships L<150m the steel weight increase is around 3%

The weight increments arise both from skin plates and transverse members.

The weight increments come mainly from local scantling check, followed by direct strength analysis and then hull girder ultimate strength check. The contribution from fatigue strength analysis is almost negligible.

<table>
<thead>
<tr>
<th>Type</th>
<th>ID No.</th>
<th>Size</th>
<th>S-25</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Capesize compliant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D2</td>
<td>Handymax</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D3</td>
<td>Handymax</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D4</td>
<td>Capesize compliant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D5</td>
<td>Capesize compliant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>Capesize</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>Panamax</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>Handymax</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S4</td>
<td>Capesize</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S5</td>
<td>Panamax</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S6</td>
<td>Panamax compliant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS1</td>
<td>Mini-Handy &lt;150m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS2</td>
<td>Mini-Handy &lt;150m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS3</td>
<td>Mini-Handy &lt;150m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. SOME PRACTICAL COMMENTS

The common structural rules will result in a more rational approach to shipbuilding standards and classification societies will work to the same set of detailed rules.

This does not mean that classification societies will lose their individuality. They will not. It simply means that there will be no room for compromise on structural scantlings. Bureau Veritas believes in helping shipyards to build stronger ships in the most efficient and cost-effective manner. BV believes that greater co-operation between classification societies, regulators and shipyards, and a commitment to working closely with shipowners, operators and charterers, will result in safer and cleaner shipping for everyone.

6.1 HARMONISATION

The common structural rules for tankers and bulk carriers began at different points in time and initially followed individual paths of development. IACS member societies agreed to harmonise the two approaches and a high degree of harmonisation between the two sets of rules has already been achieved. The wording adopted by individual societies in relation to the IACS common structural rules is identical and work on further harmonisation will continue.

The process was divided into three terms, a short term, a medium term and along term harmonisation process.

The short term would focus on:
- Vertical wave shear force
- Corrosion additions and allowances
- Ultimate hull girder strength

The medium term on:
- Prescriptive buckling
  - Buckling under hull girder loads, not in FE
  - Direct analysis comparison
- Direct strength Analysis
  - To eliminate the major concern against two procedures with regard to common scantlings
  - Comparative analysis of Tanker and Bulker structures by JTP and JBP teams

The long term on:
- Loads harmonisation
• Fatigue

The short and medium term tasks have been completed and the result is included in the final text. The Long term projects are tasked to expert groups under the supervision of the IACS hull panel.

6.2 RECOGNITION FOR COMPLIANCE

For tankers and bulk carriers of the specified dimensions contracted after 1st April 2006, there will be a new class notation CSR added to the service notation which will signify that vessels are in compliance with the IACS Common Structural Rules. This will be standard procedure for all classification societies which are members of IACS.

6.3 SOFTWARE

There is no current intention of IACS to develop its own software tools relating to the Common Structural Rules, however it is up to individual IACS member societies to thoroughly check that their software correctly produces the common results.

Bureau Veritas MARS was used from the beginning by the Joint Bulk Carrier Project as the benchmark for the strength calculations of the hull girder and of the local scantlings of any transverse section along the ships length for different failure modes such as yielding, buckling, ultimate strength and fatigue. MARS is also available to do the same for the new tanker rules. MARS can be downloaded from the Bureau Veritas web site www.veristar.com

VeriSTAR Hull is the well known Bureau Veritas finite element analysis software supporting the common structural rules for both tankers and bulk carriers. VeriSTAR Hull can be used as a design and verification program as well as an operational and management tool for an owner to continue to monitor the vessels condition.

These tools are available to ship designers, ship builders and owners in support of the Common Structural Rules.

7. CONCLUSION

Today it is almost three years ago that the JBP project started. With the coming into force at the 1st of April IACS has concluded a major undertaking. Common structural rules will set a common standard. There will be no more competition on scantlings.

Clear corrosion margin and allowance, which means that the actual strength is calculated for the in service state, as well as it will dissolve long discussion on which percentage of wastage should be taken to determine plate renewal. The common rule format provides transparency and consistency.

More robust ships are ensured through:

• Explicit Hull Girder Ultimate Limit State check to confirm overall hull girder safety
• Increased minimum fatigue standards
• Fatigue with 25 years North Atlantic environment:
• Design life of 25 years, wastage allowance selected to be in line with accumulated experiences

8. REFERENCES