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Consequence Assessment (CA) – Summary Report

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Summary:

Consequence assessment has been carried out in order to determine the effect of applying the 01 January 2014 release of the Common Structural Rules (CSR-H).

Detailed consequence assessment results are reported in separate individual Technical Background reports. An explanation and summary of the CA report results are presented herein.

Revision History:

CONTENTS

1 Introduction

1.1 General

Consequence assessment (CA) has been carried out in order to determine the effect of applying the 1 January 2014 version of the Common Structural Rules (CSR-H).

In the CA evaluation IACS Societies have used current and representative designs from major builders in Asia – the ships used in the CA are listed in Sec 5 of this report. The designs assessed in this CA are compliant with the July 2010 of the Common Structural Rules. For the consequence assessment the design has not been altered in any way. Strake size, seam locations, material properties, stiffener spacing etc. have not been altered.

The detailed CA results are reported in separate individual Consequence Assessment reports, see Table 1 and Table 2 for list of detailed report for oil tankers and bulk carriers respectively. An explanation and summary of the CA report results are presented herein.

Table 1: Consequence Assessment reports for oil tankers

CA Ship – Oil Tanker	CA Report Filename
VLCC	CA Rep_OT1_VLCC
	CA Rep_OT2_VLCC
Suezmax	CA Rep_OT3_Suezmax
	CA Rep_OT4_Suezmax
Aframax	CA Rep_OT5_Aframax
	CA Rep_OT7_Aframax
Panamax	CA Rep_OT8_Panamax
	CA Rep_OT9_Panamax
Handymax	CA Rep_OT10_Handymax

Table 2: Consequence Assessment reports for bulk carriers

CA Ship – Bulk Carrier	CA Report Filename
Capesize	CA Rep_BC1_Capesize
	CA Rep_BC2_Capesize
	CA Rep_BC3_Capesize
Babycape	CA Rep_BC4_Babycape
	CA Rep_BC5_Babycape
Panamax	CA Rep_BC6_Panamax
	CA Rep_BC7_Panamax
Handymax	CA Rep_BC8_Handymax
	CA Rep_BC9_Handymax
	CA Rep_BC10_Handymax

1.2 Summary overview

In Sec 2, the method and assumptions behind the consequence assessment is described.

In Sec 3, the preparation and presentation of the detailed CA results in the detailed CA reports are explained.

In Sec 4, the cross checking activity is described. The consequence assessment is carried out using available software from each Classification Society. An integral part of the consequence assessment is the cross checking activity whereby the results of software is cross checked against other classification society software.

In Sec 5, an overview of the test ships used in the consequence assessment is given.

In Sec 6, a summary of the detailed consequence assessment results are provided. The detailed CA results are reported in separate individual Technical Background reports as listed above.

2 Methods and Assumptions

2.1 General

The CA results are presented in comparison against the Common Structural Rules, and against the offered design, namely:

- CSR-H rule requirements against CSR-BC or CSR-OT. This comparison provides information solely on the rule requirements.
- CSR-H rule requirements against the offered design. This comparison provides information on the designs against the 1 January 2014 version of the CSR-H Rules.

Representative cross sections have been selected along the ship length from the aft part to the fore part, and CA results provided at these regions. See figure 1 for overview of the locations.

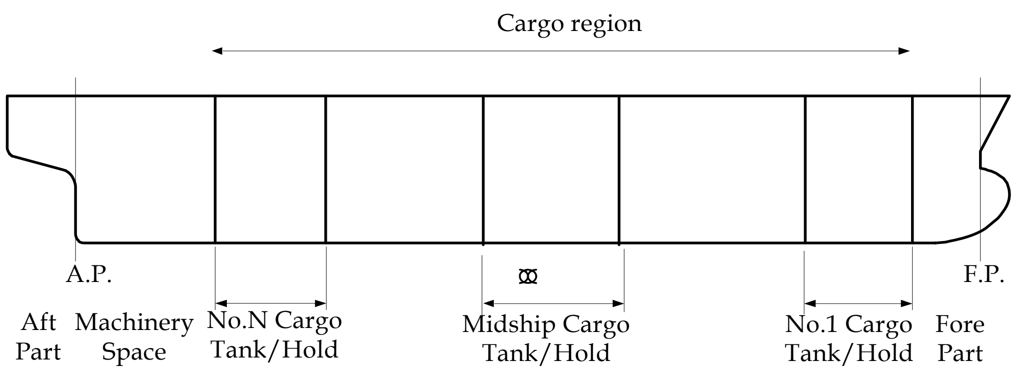


Figure 1: Overview of consequence assessment locations

For each of the regions listed below a section at about mid-length have been selected for reporting results:

- Aft Part.
- Machinery Space.
- No. N cargo hold/tank, i.e. the last cargo hold/tank.
- Midship cargo tank/hold. For oil tanker one cross section is reported in the midship cargo oil tank. For bulk carrier up to three cargo holds is reported covering loaded hold, empty hold, and ballast hold.
- No.1 cargo hold/tank.
- Fore Part.

In addition to the above locations one selected transverse bulkhead and primary support member results have also been reported:

- Transverse bulkhead; the forward bulkhead in the midship cargo tank/hold.
- Horizontal stringers on the selected transverse bulkhead.
- Primary support members – transverse web frame in the midship cargo tank.

Prescriptive results for all strakes and stiffeners have been reported for both CSR and CSR-H covering regions listed above. Prescriptive buckling results are reported as they are calculated in the Rules, i.e. buckling usage factors. For some locations in some reports scantling increase estimates have been made to estimate scantling needed to satisfy the CSR-H buckling requirements.

For finite element assessment results, please refer to 3.4. For finite element assessment for yielding and buckling whenever the offered scantlings does not satisfy CSR-H scantling increase estimates have been carried out in some limited cases. Otherwise yielding and buckling usage factors are report, please refer to 3.4 for method of reporting.

The increase estimates calculated are approximations of the scantlings that may be needed to satisfy the CSR-H requirements. In the computation of the estimates approximate methods have been used to arrive at the scantling estimates, and the design have not been modified. Therefore the final scantlings will not become apparent before new designs have been generated.

For the consequence assessment and in the estimation of the scantling increases and decreases the design has not been altered in any way. Strake size, seam locations, material properties, stiffener spacing etc. have not been altered.

3 Results Presentation

3.1 General

The CA results are presented in tables covering plates and stiffeners separately. In the figure, and tables below one example is shown to illustrate the detailed reporting.
The figures and tables in the detailed consequence assessment reports use the nomenclature defined in the glossary in App A.

For each of the sections the following is reported.

- Plating results covering, prescriptive yielding, prescriptive buckling, FE yielding, FE buckling (FE results depends on results availability).
- Stiffener results are reported in two tables:
  - Stiffener results covering prescriptive yielding, prescriptive buckling, FE yielding, FE buckling (FE results depends on results availability).
  - Stiffener results covering simplified fatigue is reported in a separate table.

3.2 Overview

In the detailed report a figure, see Figure 2 for example, is included to show the cross section, strake locations, and labelling of the strakes.

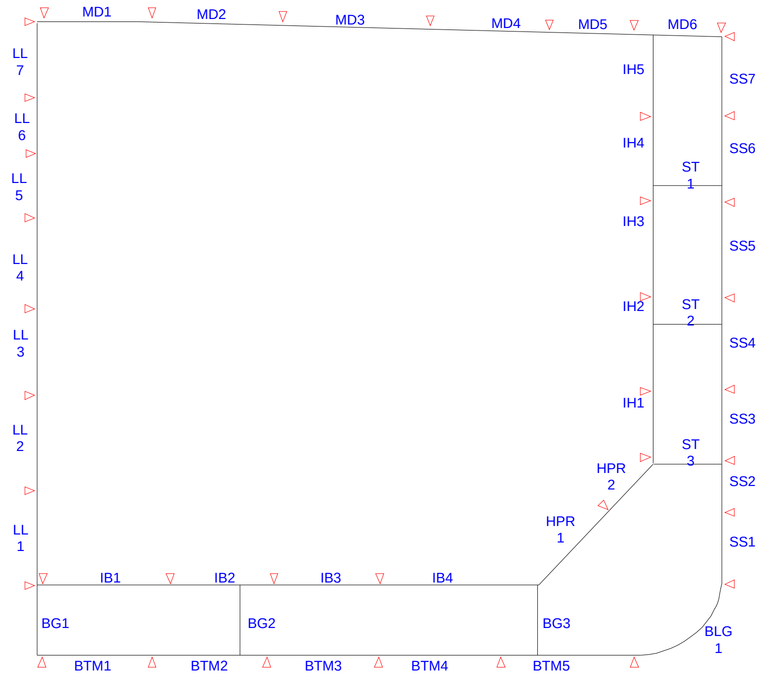


Figure 2: Oil Tanker cross section example showing strake labelling and locations

3.3 Detailed results presentation

An extract of a detailed report is shown in Table 3 to illustrate how the plating results are presented in the detailed CA report. Each column is described below the table.

Table 3: Consequence assessment report for plating results

Plating

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)

Ref.	Offered Net thickness [mm]	Prescriptive							Increase scantling impact			
		CSR			CSR-H			Difference in net CSRH-CSR [mm]	CSR-H			Difference in net max Final-Offered [mm]
		CSR Net Req. [mm]	Criterion	CSR Buckling	CSRH Net. Req. [mm]	Criterion	CSRH Buckling	Note 1	Final Presc [mm] Note 2	Final FE [mm] Note 3	Criteria	
IH1	13.5	13.5	Local	0.53	14.0	Local	0.59	0.5	14.0	13.5	Local	0.5
IH2	12.0	12.0	Local	0.57	13.0	Local	0.68	1.0	13.0	12.0	Local	1.0
IH3	11.5	11.0	Local	0.96	11.5	Local	0.90	0.5	11.5	12.0	FE Buck	0.5

NOTES:
Note 1 Difference is excluding buckling
Note 2 Final prescriptive requirement is the maximum between offered and prescriptive yielding and prescriptive buckling.
Note 3 Final FE requirement is the maximum between offered and FE yielding, FE buckling.

(a) These two columns show the strake label and offered net thickness.
(b) These two columns indicate the prescriptive CSR required net thickness and the governing criteria, excluding prescriptive buckling.
(c) CSR prescriptive normalised buckling utilisation factors are shown in this column.
(d) These two columns indicate the prescriptive CSR-H required net thickness and the governing criteria, excluding prescriptive buckling.
(e) CSR-H prescriptive normalised buckling utilisation factors are shown in this column.
(f) Difference in the rule requirement is calculated, i.e. Rule to Rule comparison excluding prescriptive buckling.
(g) Final prescriptive requirement is the maximum between offered and prescriptive yielding and estimated prescriptive buckling.
(h) Final FE requirement is the maximum between offered and estimated FE yielding, and FE buckling.
(i) Governing criteria.
(j) Difference between the CSR-H rule requirements and the offered scantling is calculated, i.e. the impact on the design.

An extract of a detailed report is shown in Table 4 to illustrate how the stiffener results are presented in the detailed CA report.

Table 4: Consequence assessment report for stiffener results

Stiffeners

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)

Ref.	Net Offered SM [cm3]	Prescriptive							Increase scantling impact			
		CSR			CSR-H			[CSRH - CSR] / CSR [%] Note 1	CSR-H			Difference in net max Final [CSRH-Offered] / Offered [%]
		CSR Net Req. SM [cm3]	Criterion	CSR Buckling	CSRH Net. Req. SM [cm3]	Criterion	CSR-H Buckling		Final Presc [cm3] Note 2	Final FE [cm3] Note 3	Criteria	
IH28	1210	1153	Local	0.26	1282	Local	0.4	11.2	1282	1282	Local	5.9
IH29	1117	1100	Local	0.19	1208	Local	0.3	9.8	1208	1208	Local	8.2
IH31	993	995	Local	0.16	1109	Local	0.2	11.5	1109	1109	Local	11.7
IH32	996	942	Local	0.16	1060	Local	0.3	12.5	1060	1060	Local	6.4
IH33	873	827	Local	0.17	941	Local	0.3	13.8	941	941	Local	7.8

NOTES:
Note 1 Difference is excluding buckling
Note 2 Final prescriptive requirement is the maximum between offered and prescriptive yielding and prescriptive buckling.
Note 3 Final FE requirement is the maximum between offered and FE yielding, FE buckling.

(a) These two columns show the stiffener label and offered net section modulus.
(b) These two columns indicate the prescriptive CSR required net section modulus and the governing criteria, excluding prescriptive buckling.
(c) CSR prescriptive normalised buckling utilisation factors are shown in this column.
(d) These two columns indicate the prescriptive CSR-H required net section modulus and the governing criteria, excluding prescriptive buckling.
(e) CSR-H prescriptive normalised buckling utilisation factors are shown in this column.
(f) Difference in the rule requirement is calculated, i.e. Rule to Rule comparison excluding buckling. The difference is indicated as a percentage difference in required section modulus calculated as [CSRH - CSR] / CSR, in %.
(g) Final prescriptive requirement is the maximum between offered and prescriptive yielding and estimated prescriptive buckling.
(h) Final FE requirement is the maximum between offered and estimated FE yielding, and FE buckling.
(i) Governing criteria.
(j) Difference between the CSR-H rule requirements and the offered scantling is calculated, i.e. the impact on the design.

Table 5 is an extract to illustrate how the stiffener results covering simplified fatigue of longitudinal stiffeners are presented in the detailed CA report.

Table 5: Consequence assessment report for simplified fatigue results

Fatigue Results

Reference	CSR Fatigue Life (Y)		CSRH Fatigue Life (Y)		Difference CSRH - CSR (Y)	
	Hot Spot		Hot Spot		Hot Spot	
	After	Fore	After	Fore	After	Fore
BTM1	N/A	N/A	80	82	N/A	N/A
BTM2	208	128	56	49	-151	-78
BTM3	192	111	54	47	-138	-65
BTM4	177	97	52	44	-125	-53
BTM5	162	84	49	41	-113	-43
BTM6	142	123	45	47	-97	-76

3.4 Finite element results presentation

Finite element comparison results are presented in a series of plots to show the main structural members in the target region (mid tank/hold of the three tank/hold model). Two groups of plots for finite element yielding and buckling evaluation are reported:

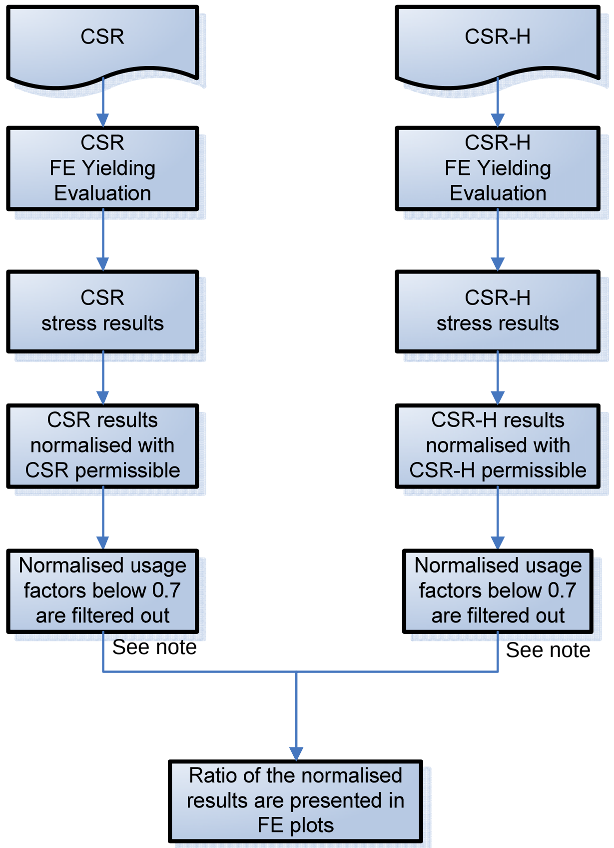
- Rule to Rule comparison
- CSR-H rule assessment

The FE CA is based on the offered design scantlings, and the scantlings are not modified as a result of the CSR-H prescriptive evaluation.

3.4.1 Consequence assessment plots for finite element yielding evaluation

Two groups of plots for finite element yielding evaluation are presented; namely *Rule to Rule comparison* and *CSR-H yielding assessment*.

- Rule to Rule comparison
  In the Rule to Rule comparison the same model (based on the offered scantlings) is evaluated in accordance with CSR and CSR-H. The results are normalised with the permissible utilisation factors as defined in the respective Rules. See Figure 3 for process followed in preparation of the plots. The ratio of the normalised results are plotted and presented in the detailed reports.



(Note: When both normalised usage factors in CSR and CSR-H are below 0.7, the comparison results are filtered out.)

Figure 3: Process for preparation of Rule to Rule comparison FE plots (see Figure 4 for example plot)

Ratio of normalised usage factor (CSR-H/CSR) of cargo hold strength analysis is calculated and reported.

Ratio of normalised usage factors: $\dfrac{\lambda_{CSR-H}}{\lambda_{CSR-H-perm}} \Big/ \dfrac{\lambda_{CSR}}{\lambda_{CSR-perm}}$

Items with a normalised usage factor below 0.7 for both rules (CSR and CSR-H), for yielding evaluation are filtered out for an improved overview, see Table 6.

Table 6: Ratio of normalised usage factor and consequence

Ratio of normalised usage factor	
> 1.0	CSR-H FE yielding analyses results are more conservative than CSR
= 1.0	CSR-H FE yielding analyses results are equal to CSR
< 1.0	CSR-H FE yielding analyses results are less conservative than CSR
< 0.7	Results with usage factor below 0.7 are filtered out for an improved overview, and these areas will be shown as white in the FE output plots. When both normalised usage factors in CSR and CSR-H are below 0.7, the comparison results are filtered out.

Rule to Rule comparison example plot of ratio of normalised usage factor is shown in Figure 4.

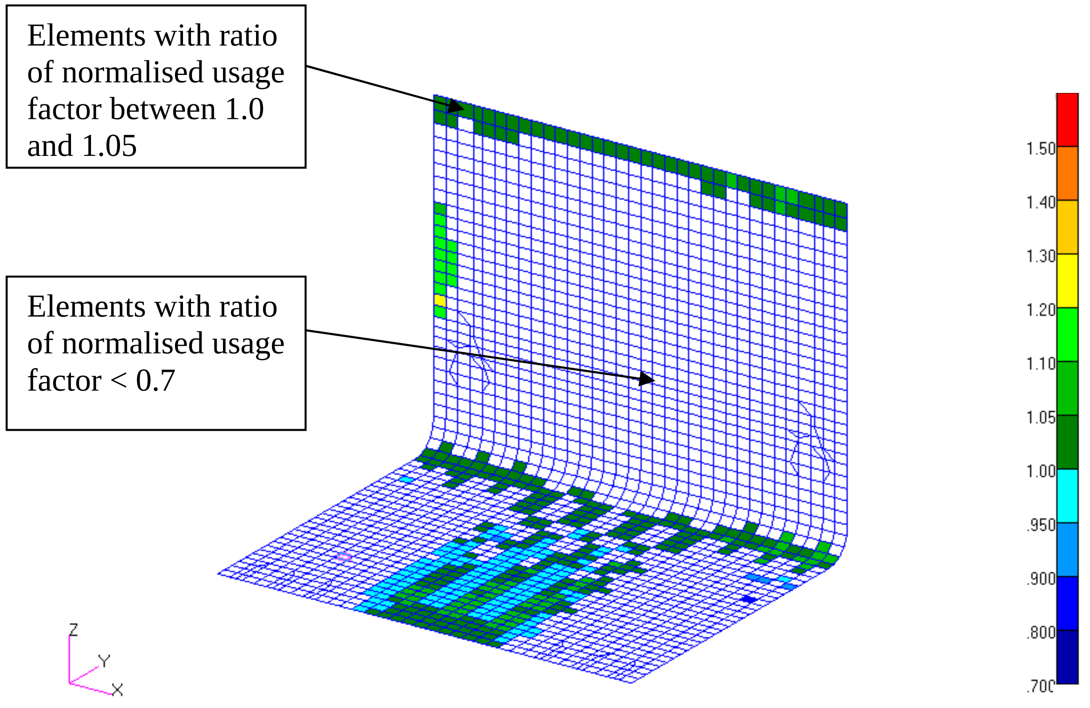


Figure 4: Example plot showing bottom and side shell for Rule to Rule comparison of normalised usage factors

- CSR-H yielding assessment. In CSR-H yielding assessment the same model (based on the offered net scantlings) is evaluated in accordance with CSR-H. The results are normalised with the permissible utilisation factors as defined in the Rules. See Figure 5 for process followed in preparation of the plots. The CSR-H normalised results are plotted and presented in the detailed reports.

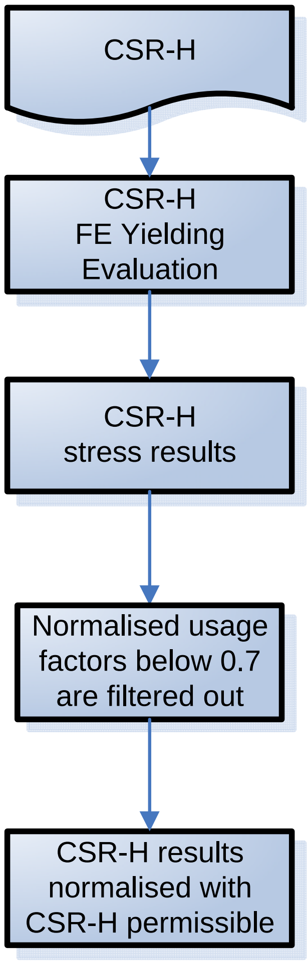


Figure 5: Process for preparation of CSR-H assessment FE plots (see Figure 6 for example plot)

Normalised yield usage factor of cargo hold strength analysis.

CSR-H normalised usage factors: $\dfrac{\lambda_{CSR-H}}{\lambda_{CSR-H-perm}}$

Results below 0.7 in CSR-H are filtered out for an improved overview, see Table 7.

Table 7: CSR-H normalised usage factor and consequence

CSR-H normalised usage factor	
> 1.0	Offered design does not comply with CSR-H FE requirements
$\leq$ 1.0	Offered design comply with CSR-H FE requirements
< 0.7	Results with usage factor below 0.7 are filtered out for an improved overview, and these areas will be shown as white in the FE output plots

CSR-H analysis example plot of CSR-H normalised usage factor is shown in Figure 6.

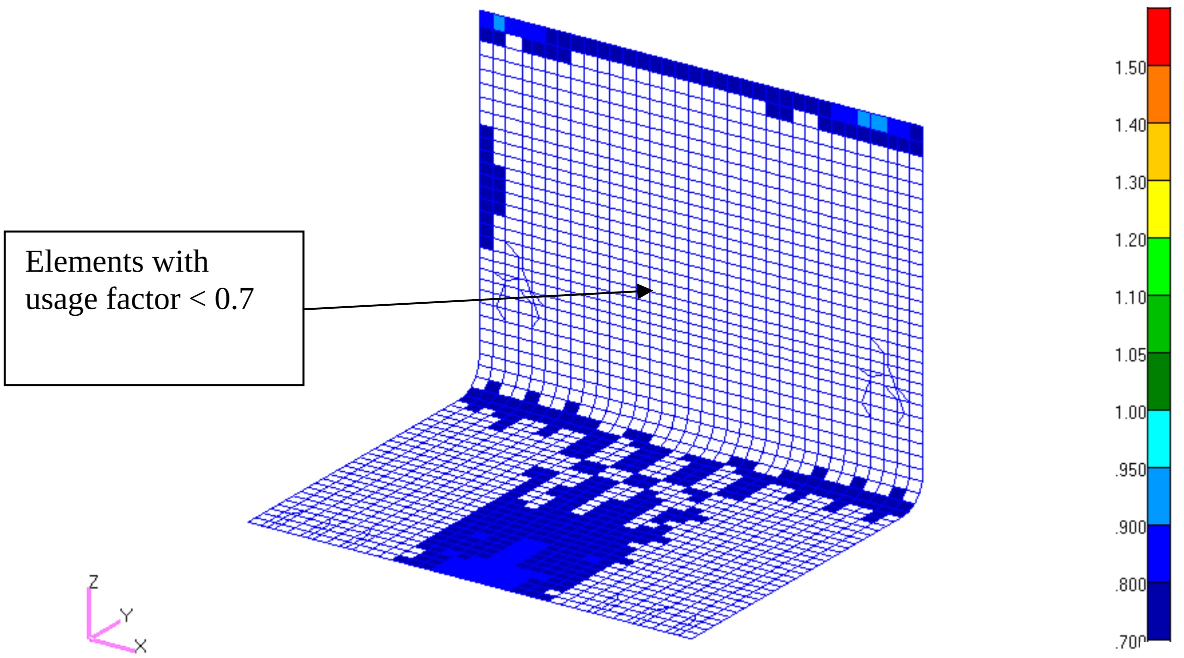


Figure 6: Example plot showing bottom and side shell for CSR-H evaluation

3.4.2 Consequence assessment plots for finite element buckling evaluation

Two groups of plots for finite element buckling evaluation are presented.

- Rule to Rule comparison
  Ratio of normalised usage factor (CSR-H/CSR) of cargo hold buckling analysis in mid-ship area.

  Ratio of normalised usage factors: $\dfrac{\eta_{CSR-H}}{\eta_{CSR-H-perm}} \Big/ \dfrac{\eta_{CSR}}{\eta_{CSR-perm}}$

  Items with a usage factor below 0.70 for both rules (CSR and CSR-H), for buckling evaluation are filtered out. All other results are included.

- CSR-H rule buckling assessment
  Normalised buckling usage factor of cargo hold buckling analysis.

  CSR-H normalised usage factors: $\dfrac{\eta_{CSR-H}}{\eta_{CSR-H-perm}}$

  Results below 0.7 in CSR-H are filtered out for an improved overview.

The FE buckling results are plotted and presented in a similar format as the FE yielding results in a series of FE output plots.

4 Cross Checking

4.1 General

The consequence assessment is carried out using software from each individual class society. Before CA is carried out it is important to verify that the Rules have been correctly interpreted and implemented in the software. To ensure correct implementation cross checking is carried out using a common ship; one tanker and one bulk carried is used in the cross checking activity.

The two ships used in the cross checking are not used in the consequence assessment.

The CSR-H rules are applied on the common ships, and the output is compared. We can proceed to consequence assessment only when satisfactory cross checking comparison is carried out. Cross checking is carried out for prescriptive as well as finite element requirements. The cross checking process is illustrated in Figure 7.

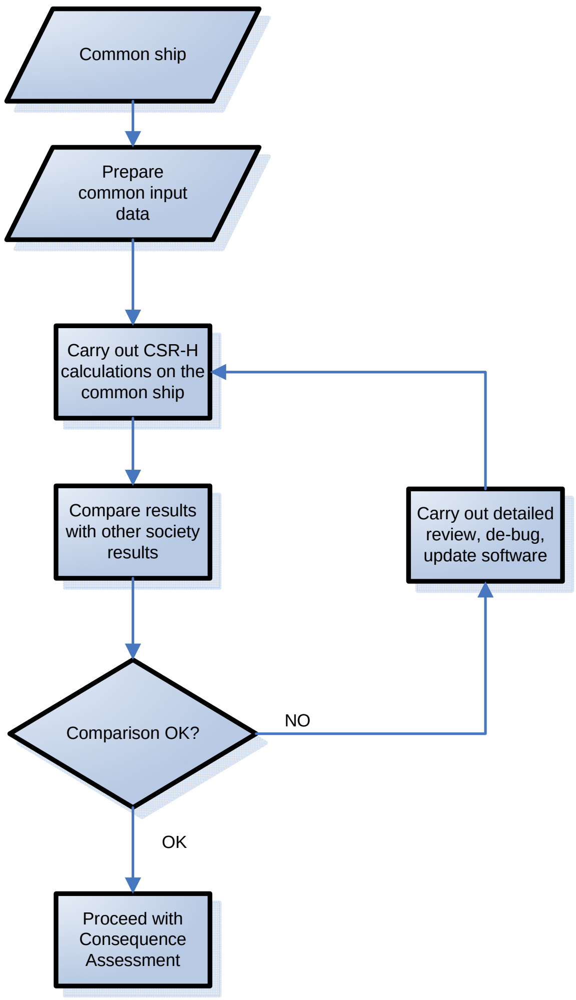


Figure 7: Process for cross checking

The cross check results will be reported for the draft CSR-H rule version. The cross check of the individual software tools, based on the latest rule revision show sufficient agreement for all IACS Societies.

5 Consequence Assessment – Test Ships

5.1 Oil Tankers

Table 8: Principal particulars of the oil tankers

ID	Category	*LBP* (m)	*Bmld* (m)	*Tsc* (m)	*Dmld* (m)	Dwt. (tonnes)
OT1	VLCC	319	60.0	22.6	30.4	318000
OT2		324	60.0	21.0	29.0	330000
OT3	Suezmax	264	48.0	17.0	23.7	158000
OT4		264	50.0	17.0	23.2	163000
OT5	Aframax	240	42.0	15.0	21.5	97000
OT7		234	42.0	15.0	21.2	105000
OT8	Panamax	220	32.3	14.7	21.2	76000
OT9		219	32.2	14.5	20.9	74000
OT10	Handymax	176	32.2	12.6	18.2	50500

5.2 Bulk Carriers

Table 9: Principal particulars of the bulk carriers

ID	Category	*LBP* (m)	*Bmld* (m)	*Tsc* (m)	*Dmld* (m)	Dwt. (tonnes)
BC1	Capesize	285	46.0	18.1	24.8	180239
BC2		284	45.0	18.2	24.7	180000
BC3		293	50.0	18.4	24.9	205000
BC4	Baby Cape	240	43.0	15.0	21.3	114500
BC5		248	43.0	14.5	20.2	115000
BC6	Panamax	225	32.0	14.0	20.0	82000
BC7		223	32.0	15.0	20.0	81000
BC8	Handymax	183	32.3	12.6	17.5	53000
BC10		185	32.0	14.0	18.0	56000
BC8 is double side skin bulk carrier.						

6 General Consequence Assessment Summary

6.1 Introduction

Consequence assessment results supplied by IACS members based on the 1 January 2014 version of the CSR-H have been assembled. A review of the CA results indicates general trends which are detailed in this section. The detailed results are available in the individual reports, and in some cases the individual results may not follow the trend which may be due to difference in design.

The consequence assessment covers:

- local scantling requirements (yielding, buckling, and simplified fatigue assessment)
- Hull girder ultimate strength and hull girder ultimate residual strength
- Direct strengths assessment (yielding, buckling assessment, and fatigue assessment)

Scantlings as a result of considering hull girder strength (including ultimate strength) is not included in the CA results. The scantlings which are predicted to be governed by hull girder considerations have been indicated in the detailed results tables with a note in the tables: (NOTE *: Offered thickness is determined by hull girder strength.).

6.2 Oil Tankers – general summary

6.2.1 Midship cargo tanks

In general keel, sheer strake plating and non-watertight girders in double bottom and non-watertight stringers in the double hull will see scantling increase for most of the tankers assessed. This is due to the minimum thickness increase.

The plating results indicate +0.5 to +1.0mm increase for the inner hull, hopper and longitudinal bulkhead plating in order to satisfy CSR-H.

Main deck longitudinal stiffener section modulus requirements in CSR-H yielding and CSR-H buckling requirement are generally more conservative than CSR. This leads to scantling increase in most ships.

Longitudinal bulkhead and inner hull longitudinal stiffener section modulus requirements in CSR-H yielding and CSR-H buckling requirements are generally more conservative than CSR. This leads to scantling impact in some locations.

Offered scantlings generally satisfy the simplified fatigue assessment requirements in accordance with CSR-H. Some longitudinal stiffeners have fatigue life in the order of 20 to 25 years and these are located in the bottom shell and side shell.

Finite element yielding assessment has limited impact for the oil tankers. Finite element buckling assessment leads to scantling impact. Generally the following structure has areas which do not satisfy CSR-H buckling requirements:

- Hopper structure
- Inner hull upper part
- Longitudinal bulkhead upper part
- Horizontal stringers in the double hull
- Double bottom floors

6.2.2 Foremost cargo tank

In general keel, sheer strake plating and non-watertight girders in double bottom and non-watertight stringers in double hull will see scantling increase for most of the tankers assessed. This is due to the minimum thickness increase.

Inner bottom plating for most tankers shows CSR-H rule requirement for plating is -0.5mm in comparison to CSR except that requirements are equivalent for Suezmax tankers. Bilge plating show CSR-H is more conservative than CSR due to local pressure yielding assessment. In some areas scantling increase of +1.0mm is seen.

6.2.3 Aft most cargo tank

In general keel, sheer strake plating and non-watertight girders in double bottom and non-watertight stringers in double hull will see scantling increase for most of the tankers assessed. This is due to the minimum thickness increase.

6.2.4 Fore part

CSR-H rule requirements for plating and stiffeners are generally more conservative than CSR. Some scantling increase is observed in comparison with the offered scantlings.

6.2.5 Aft part

CSR-H rule requirements for plating and stiffeners are generally more conservative than CSR. Some scantling increase is observed in comparison with the offered scantlings.

6.2.6 Machinery space

CSR-H rule requirements for plating and stiffeners are generally more conservative than CSR. Some scantling increase is observed in comparison with the offered scantlings.

- Suezmax; CSR-H buckling requirements is causing scantling increase. Scantling increase of up to +3.5mm for side shell including sheer strake. Bottom shell, side shell and main deck have few strakes failing in buckling.
- Panamax; CSR-H buckling requirements is causing scantling increase for the bilge plating. Scantling increase of up to +4.5mm for bilge plating.

6.2.7 Transverse bulkhead

The assessment of a typical bulkhead on the VLCC (OT1 & OT2), Suezmax (OT3), Aframax (OT5, OT7), and Panamax (OT8, OT9) type vessels shows increases on some of the vessels to the plating thickness and stiffener section modulus rule requirements. The increase is seen in the upper part and lower of the bulkhead; for plating thickness the increase is about +0.5mm to +2.0mm. The increased rule requirements for stiffener section modulus leads to no or very moderate section modulus increases. The governing criterion is local pressure.

CSR-H FE yielding assessment does not lead to any scantling increase.

CSR-H FE buckling assessment shows that the offered scantlings are not sufficient in some locations. Increase in the order of +0.5mm may be expected in comparison with the offered scantlings.

Horizontal stringers on the transverse bulkhead see moderate or no increase on the plating thickness and section modulus.

6.2.8 Transverse web frame

The assessment of a typical web frame on the VLCC (OT2), Suezmax (OT3), Aframax (OT5), and Panamax (OT9) type vessels shows increases due to FE buckling and/or FE yielding. The increase is in the order up to +3.5mm.

The prescriptive CSR-H rule requirements are more conservative for plating and stiffeners.

6.3 Oil Tankers – Hull girder ultimate strength & residual strength

The hull girder ultimate strength results are summarised in table 10 below. No scantling increase is necessary except on the Suezmax OT3. The Hull girder ultimate residual strength results were reviewed for oil tanker and no scantling increase was seen.

Table 10: Oil Tankers – Overview of hull girder ultimate strength and residual strength results (governing results are reported in the summary)

Hull Girder Ultimate Strength (HGUS)

Location	OT2	OT3	OT4	OT5	OT7	OT8	OT9	OT10
	VLCC	S'max	S'max	A'max	A'max	P'max	P'max	H'max
Midship cargo tank	99.4%	101.8%	92.1%	96.4%	91.6%	86.1%	81.8%	96.0%
Foremost cargo tank	OK	OK	OK	OK	OK	OK	OK	OK
Aftmost cargo tank	OK	OK	OK	OK	OK	OK	OK	OK
Machinery Space	OK	OK	OK	N/A	OK	OK	OK	OK

Hull Girder Ultimate Residual Strength (HGURS)

Location	OT2	OT3	OT4	OT5	OT7	OT8	OT9	OT10
	VLCC	S'max	S'max	A'max	A'max	P'max	P'max	H'max
Midship cargo tank Grounding	85.8%	72.6%	76.5%	75.0%	69.0%	64.2%	66.2%	63.0%
Midship cargo tank Collision	98.2%	85.0%	70.2%	84.3%	85.0%	65.9%	65.8%	70.0%
Foremost cargo tank	OK	OK	OK	OK	OK	OK	OK	OK
Aftmost cargo tank	OK	OK	OK	OK	OK	OK	OK	OK
Machinery Space	OK	OK	OK	N/A	OK	OK	OK	OK

Percentage is calculated as: $M\gamma_R$ / M_u x 100; <100%: OK
Symbols are as used in the Rules Ch.5, Sec.2, [2.1.2].

6.4 Oil Tankers – FE outside midship general summary

There is currently no finite element procedure in CSR covering the areas outside midship region. Impact analyses have been undertaken to identify any consequences on individual designs.

For the VLCC, Suezmax, Aframax, and Panamax vessels the FE yielding assessment of the foremost and aftmost tanks does not generally lead to large scale scantling increase. The offered scantlings generally satisfy CSR-H FE yielding assessment criteria; localised increases may be necessary, and in some instances the locations are screening locations where fine mesh analysis may be required.

An overview summary of the yielding and buckling results are shown in Table 10.

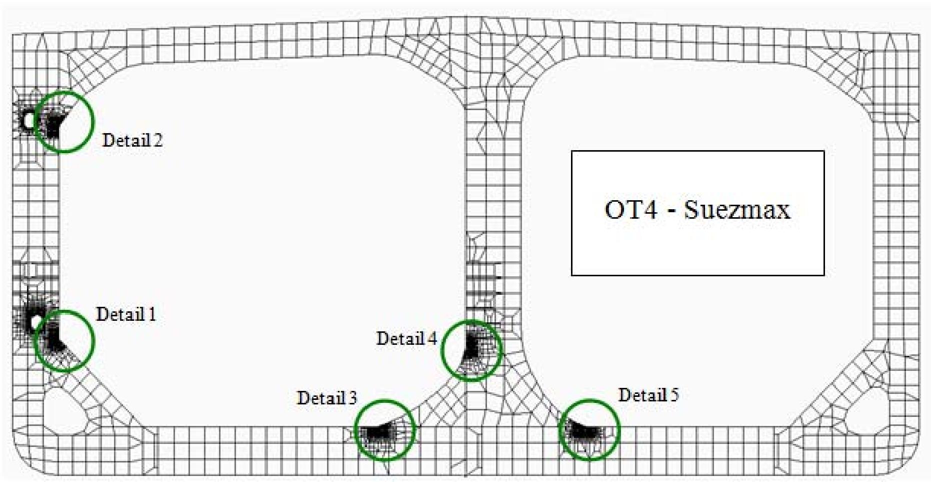
Table 11: Oil Tankers – Overview of impact analyses for foremost and aftmost cargo oil tank finite element analyses

Oil Tanker		Aftmost cargo oil tank		Foremost cargo oil tank	
		Yielding assessment	Buckling assessment	Yielding assessment	Buckling assessment
VLCC	OT2	Local increase	Some increase is seen	Local increase	Some increase is seen
Suezmax	OT3	Local increase	Some increase is seen	Local increase	Some increase is seen
	OT4	No increase is seen	Some increase is seen	No increase is seen	Some increase is seen
Aframax	OT5	No increase is seen	Some increase is seen	Modest impact is seen	Some increase is seen
	OT7	No results		Modest impact is seen	Some increase is seen
Panamax	OT8	No results		Local increase	Some increase is seen
	OT9	Modest impact is seen	Some increase is seen	Local increase	Some increase is seen
Handymax	OT10	No increase is seen	Some increase is seen	No increase is seen	Modest impact is seen

6.5 Oil Tankers – local fine mesh

Results of CSR-H for fine mesh (yielding) structural strength analysis in the midship cargo tank have been reviewed for the following ships.

- VLCC OT2; results for the lower and upper hopper knuckle indicates local increase will not be needed. Results for the longitudinal stiffener connection in the double bottom and deck area indicate that increases will be needed.
- Suezmax OT3; Long stiffeners to transverse bulkhead indicates local increase will not be needed in way of the toe of the bracket.
- Suezmax OT4; five details, as shown in figure below, have been investigated, and results indicates no scantling increase except for face plate of bracket on detail 3.



- Aframax OT5; two locations have been analysed and the findings are:
  - Lower hopper knuckle of bent type indicates no scantling increase.
  - Local reinforcement is needed for deck longitudinals to transverse bulkhead.
- Panamax OT8; results for lower hopper knuckle indicates local increase will not be needed.
- Panamax OT9; the following locations have been investigated, and results indicates no scantling increase except as noted below.
  - Deck longitudinal at bulkhead connection.
  - No.1 stringer toe connection; stringer toe will need modification.
  - No.2 stringer toe connection.
  - No.3 stringer toe connection.
  - Double bottom opening at the adjacent aft web from transverse bulkhead.
  - Vertical stiffener on transverse bulkhead connection to inner bottom.
  - Double bottom stiffener connections on the transverse bulkhead.
  - Openings on hopper web at the adjacent web from the transverse bulkhead.
  - Opening on double bottom web at the adjacent web from the transverse bulkhead.
  - Openings on double bottom web at a typical web.
  - Upper hopper knuckle connection.
  - Lower hopper knuckle connection.

- Handymax OT10; the following locations have been investigated, and results indicates no scantling increase.
  - Longitudinal and transverse bulkheads intersection (7 details have been analysed)
  - Transverse web ring (7 details have been analysed)

6.6 Oil Tankers – fatigue analysis by FE stress analysis

Results of CSR-H for fatigue analysis by finite element stress analysis have been reviewed for the following ship.

- VLCC OT2; lower hopper knuckle connection.

Location		Fatigue life in years CSR-H
Hopper knuckle	Hot spot #1	42
	Hot spot #2	31
	Hot spot #3	29
	Hot spot #4	40
	Hot spot #5	24

- VLCC OT2; upper hopper knuckle connection.

Location		Fatigue life in years CSR-H
Hopper knuckle	Hot spot #1	184
	Hot spot #2	58
	Hot spot #3	35
	Hot spot #4	87
	Hot spot #5	105

- Suezmax OT3; lower hopper connection,

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Radiused lower Hopper knuckle at X = 126.65 m	Hot spot #1	33.92	N/A
	Hot spot #2	40.14	N/A
	Hot spot #3	36.50	N/A
	Hot spot #4	62.21	N/A
	Hot spot #5	28.53	N/A
	Hot spot #6	137.28	N/A

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Radiused lower Hopper knuckle at X = 131.45 m	Hot spot #1	29.16	N/A
	Hot spot #2	34.92	N/A
	Hot spot #3	31.48	N/A
	Hot spot #4	50.18	N/A
	Hot spot #5	24.86	N/A
	Hot spot #6	143.79	N/A

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Radiused lower Hopper knuckle at X = 136.25 m	Hot spot #1	27.60	N/A
	Hot spot #2	32.75	N/A
	Hot spot #3	29.45	N/A
	Hot spot #4	38.73	N/A
	Hot spot #5	23.21	N/A
	Hot spot #6	130.12	N/A

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Radiused lower Hopper knuckle at X = 141.05 m	Hot spot #1	29.52	N/A
	Hot spot #2	34.20	N/A
	Hot spot #3	31.24	N/A
	Hot spot #4	47.14	N/A
	Hot spot #5	24.14	N/A
	Hot spot #6	114.60	N/A

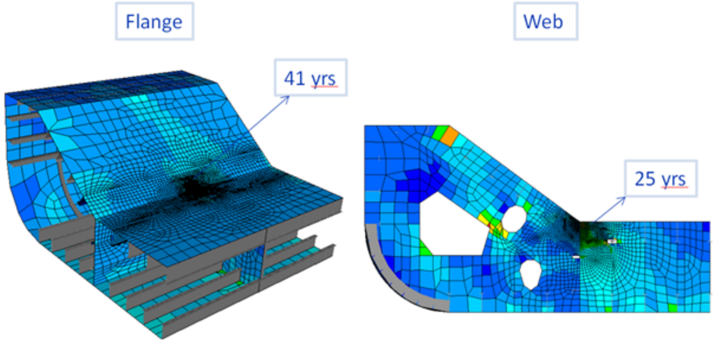
Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Radiused upper Hopper knuckle at X = 131.45 m	Hot spot #1	64.80	N/A
	Hot spot #2	55.30	N/A
	Hot spot #3	61.31	N/A
	Hot spot #4	37.88	N/A
	Hot spot #5	36.40	N/A
	Hot spot #6	54.37	N/A

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Radiused upper Hopper knuckle at X = 136.25 m	Hot spot #1	52.18	N/A
	Hot spot #2	50.72	N/A
	Hot spot #3	54.75	N/A
	Hot spot #4	36.55	N/A
	Hot spot #5	32.54	N/A
	Hot spot #6	48.15	N/A

- Suezmax OT4; lower hopper knuckle connection. Grinding is not taken into account in the following results. Results are not calculated when the hot spot location is not required in CSR.

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Hopper knuckle	Hot spot #1	22.9	22.3
	Hot spot #2	20.1	
	Hot spot #3	51.6	
	Hot spot #4	27.3	
	Hot spot #5	73.1	

- Aframax OT5; lower hopper knuckle connection (bend type).



- Aframax OT7; lower hopper knuckle connection.

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Hopper knuckle	Hot spot #1	7.1	35.0 (with toe grinding)

- Panamax OT8; lower hopper knuckle connection.

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Hopper knuckle	Hot spot #1	47.5	49.4

- Panamax OT9; lower hopper knuckle connection.

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Hopper knuckle	Hot spot #1	12.4	36.0

- Handymax OT10; lower hopper knuckle connection.

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Hopper knuckle	Hot spot #1	22.3	22.8
	Hot spot #2	27.0	
	Hot spot #3	104	
	Hot spot #4	21	
	Hot spot #5	642	

6.7 Oil Tankers – local fine mesh structural strength analysis – Screening

Results of CSR-H for local fine mesh structural strength analysis for screening have been reviewed for the following ship.

- VLCC OT2 – screening midship cargo tank

Location *Type of detail*		Screening factor λ_{sc}	Permissible screening factor λ_{scperm}
Bracket toes	L.BHD trans.	1.27	1.2
	Swash BHD	1.57	1.5
	Horizontal stringer	1.25	1.2
Heels of transverse BHD horizontal stringers	Side stringers	1.74	1.2
	Trans. BHD stringer	1.92	1.2
Notes: *Type of detail*, λ_{sc}, λ_{scperm}, is with reference to Ch 7, Sec 3, [3.3.1], Table 4.			

- VLCC OT2 – screening No.1 cargo tank

Location *Type of detail*		Screening factor λ_{sc}	Permissible screening factor λ_{scperm}
Bracket toes	L.BHD trans.	2.11	1.2
	Swash BHD	1.30	1.2
	Horizontal stringer	0.44	1.2
Heels of transverse BHD horizontal stringers	Side stringers	3.22	1.2
	Trans. BHD stringer	3.52	1.2
Hopper knuckle	Upper side	1.37	1.5
	Lower side	1.06	1.2
Notes: *Type of detail*, λ_{sc}, λ_{scperm}, is with reference to Ch 7, Sec 3, [3.3.1], Table 4.			

- VLCC OT2 – screening No.N cargo tank

Location *Type of detail*		Screening factor λ_{sc}	Permissible screening factor λ_{scperm}
Bracket toes	L.BHD trans.	1.44	1.2
	Swash BHD	1.77	1.5
	Horizontal stringer	1.44	1.2
Heels of transverse BHD horizontal stringers	Side stringers	1.91	1.2
	Trans. BHD stringer	2.21	1.2
Hopper knuckle	Upper side	1.61	1.2
	Lower side	1.42	1.2
Notes: *Type of detail*, λ_{sc}, λ_{scperm}, is with reference to Ch 7, Sec 3, [3.3.1], Table 4.			

- Suezmax OT3 – screening midship cargo tank

Location *Type of detail*	Screening factor λ_{sc}	Permissible screening factor λ_{scperm}
Heel of No.1 Side horizontal girder 1	1.35	1.2
Heel of No.1 Horizontal stringer on TBHD 2	1.34	1.2
Heel of No.1 Horizontal stringer on TBHD 3	2.29	1.2
Heel of No.1 Horizontal girder on LBHD 4	1.73	1.5
Heel of No.2 Side horizontal girder 1	1.29	1.2
Heel of No.2 Horizontal stringer on TBHD 2	1.27	1.2
Heel of No.2 Horizontal stringer on TBHD 3	2.33	1.2
Heel of No.2 Horizontal girder on LBHD 4	1.14	1.5
Heel of No.3 Side horizontal girder 1	1.34	1.5
Heel of No.3 Horizontal stringer on TBHD 2	1.91	1.2
Heel of No.3 Horizontal stringer on TBHD 3	1.87	1.2
Heel of No.3 Horizontal girder on LBHD 4	0.76	1.5
Notes: *Type of detail*, λ_{sc}, λ_{scperm}, is with reference to Ch 7, Sec 3, [3.3.1], Table 4.		

- Panamax OT9 – screening midship cargo tank

Location *Type of detail*	Screening factor λ_{sc}	Permissible screening factor λ_{scperm}
Heels of transverse bulkhead horizontal stringers (S+D)	2.37 (Max.)	1.5
Heels of transverse bulkhead horizontal stringers (S)	2.09 (Max.)	1.2
Bracket toes on horizontal stringers (S+D)	1.773 (Max.)	1.5
Bracket toes on horizontal stringers (S)	1.541 (Max.)	1.2
Notes: *Type of detail*, λ_{sc}, λ_{scperm}, is with reference to Ch 7, Sec 3, [3.3.1], Table 4.		

- Panamax OT9 – screening No.2 cargo tank

Location *Type of detail*	Screening factor λ_{sc}	Permissible screening factor λ_{scperm}
Hopper Knuckle (S+D)	1.882 (Max.)	1.80
Hopper Knuckle (S)	1.759 (Max.)	1.44
Notes: *Type of detail*, λ_{sc}, λ_{scperm}, is with reference to Ch 7, Sec 3, [3.3.1], Table 4.		

6.8 Bulk Carriers – general summary

6.8.1 Midship cargo holds

Generally the rule requirements for longitudinal stiffeners are more conservative in CSR-H (covering local pressure, prescriptive buckling) in comparison to CSR.

The GRAB requirement in CSR-H leads to scantling increases.

Some singe side shell plating does not meet the prescriptive or FE buckling requirements of CSR-H. This leads to scantling increase of various degrees.

Topside structure

- Minimum thickness for deck plating has increased for Capesize vessel but this does not generally lead to scantling increase as scantlings are dominated by hull girder requirements.
- Capesize (BC1, BC2) at most locations in the topside increase in the offered section modulus necessary to satisfy CSR-H yielding and prescriptive buckling requirements.
- Panamax (BC6) at some locations in topside bottom show slight increase in the offered net thickness and section modulus necessary to satisfy CSR-H prescriptive and FE buckling requirements.

Double bottom structure

- Bottom plating requirements shows -0.5mm, -2mm, -3mm in the Rule to Rule comparison, i.e. CSR-H is less conservative.
- Double bottom girders minimum thickness is increased by +1.0mm in Rule to Rule comparison.
- Steel Coil plating requirements in CSR-H is less conservative than CSR-BC. For the Handymax BC10 the requirement shows -1.0mm in the Rule to Rule comparison. The stiffener requirements on the contrary are more conservative in CSR-H.

Single side shell

- Capesize vessels (BC1, BC2, BC3) show scantling increase in the range from 0.5mm to +4.5mm depending on hold type due to either prescriptive buckling or FE buckling assessment.
- Babycape vessels (BC4, BC5) show no scantling increase due to CSR-H buckling.
- Panamax vessel (BC6) show scantling increase in the range from +0.5mm to +2.5mm depending on hold type due to either prescriptive buckling or FE buckling assessment.
- Handymax vessels (BC10) show no scantling increase due to CSR-H buckling.

GRAB requirement

- Capesize (BC1, BC2 and BC3) scantling increase to inner bottom plating and hopper plating ranging from +1.0mm to +3.0mm.
- Babycape (BC4 and BC5) scantling increase to inner bottom plating and hopper plating ranging from +0.5mm to +1.5mm; one strake is +3.5mm.
- Panamax (BC6) scantling increase to inner bottom plating and hopper plating ranging from +0.5mm to +1.5mm.
- Handymax (BC8, BC10) show no scantling increase due to Grab requirement.

Simplified fatigue assessment

Capesize vessel, BC1, (empty, loaded and ballast holds) has some locations with fatigue life less then CSR-H required 25 years:

- Bottom shell with few longitudinal stiffeners (12 and 22 years).
- Topside sloped plating (10 to 24 years).
- Side shell (9 to 22 years).
- Main deck (23, 24 years).

Capesize vessels – BC2 and BC3; simplified fatigue assessment generally results in fatigue life greater than 25 years for the empty, loaded and ballast holds. Only a few stiffeners have fatigue life marginally less than 25 years.

Babycape vessel – BC4; simplified fatigue assessment results in fatigue life more than 25 years.

Panamax vessel – BC6; simplified fatigue assessment generally results in fatigue life less than 25 years for the following locations:

- Main deck longitudinals (fatigue life in the range from 16 to 20years).
- Topside tank sloped plating longitudinals (fatigue life in the range from 14 to 24 years).
- Sheer strake longitudinals (fatigue life is 17 years).

Handymax vessel – BC8 and BC10; simplified fatigue assessment generally results in fatigue life more than 25 years.

FE yielding assessment:

- Capesize vessels BC1, BC2, BC3; for the empty, loaded and ballast hold generally no scantling increase is necessary. Only a few elements in the overall model need attention.
- Babycape BC4, BC5; for loaded hold and the empty/ballast hold generally no scantling increase is necessary. Only a few elements in the overall model need attention.
- Panamax BC6; for empty, loaded and ballast hold generally no scantling increase is necessary. Only a few elements in the overall model need attention.
- Handymax BC8, BC10; for empty and the loaded/ballast hold generally no scantling increase is necessary. Only a few elements in the overall model need attention.

FE buckling assessment:

The midship cargo holds of CA ships has been assessed for both yielding and buckling. The assessment has generally covered empty, loaded, and ballast holds in the midship region.

The FE buckling assessment in the midship region shows some increase in the scantlings will be necessary (assuming no changes to the design). The yielding assessment generally does not that scantling increase will be needed.

The level of increase is indicated in the individual reports.

6.8.2 Fore most cargo hold

Bottom slamming plating requirements in CSR-H is less conservative than CSR-BC. For the Capesize BC3 the plating requirement shows -3mm to -3.5mm in the Rule to Rule comparison. The stiffener requirements on the contrary are more conservative in CSR-H.

Capesize (BC3) all longitudinal stiffeners have fatigue life greater than 25 years except one.

6.8.3 Aft most cargo hold

Generally the rule requirements for longitudinal stiffeners are more conservative in CSR-H (covering local pressure, prescriptive buckling) in comparison to CSR.

Simplified fatigue assessment

Capesize (BC3) all longitudinal stiffeners have fatigue life greater than 25 years.

Capesize (BC1) and Panamax (BC6) all longitudinal stiffeners have fatigue life greater than 25 years except one.

6.8.4 Fore part

Bottom slamming plating requirements in CSR-H is less conservative than CSR-BC. For the Capesize BC3 the plating requirement shows -3.5mm in the Rule to Rule comparison. The stiffener requirements on the contrary are more conservative in CSR-H.

6.8.5 Aft part

Scantling increase is necessary for side shell plating +1.0mm to +2.0mm due to minimum thickness increase.

For Panamax (BC6) scantling increase is necessary for bottom shell plating +0.5mm due to minimum thickness increase.

6.8.6 Machinery space

Scantling increase is necessary for side shell plating +0.5mm to +1.0mm due to minimum thickness increase.

For Panamax (BC6) scantling increase is necessary for bottom shell plating, upper deck plating and longitudinal bulkhead plating +1.0mm due to minimum thickness increase.

6.8.7 Transverse bulkhead

Capesize, BC1, transverse bulkhead assessment results covering prescriptive and FE assessment are as follows:

- Bulkhead between empty and loaded hold; no increase is seen.
- Bulkhead between loaded and ballast hold; increase from +1.0mm to +7.5mm on the plating is seen due to local pressure.

Capesize, BC2, transverse bulkhead assessment results covering prescriptive assessment in the ballast hold shows no increase. The FE assessment shows that the offered scantlings are generally sufficient except some local increases may be necessary due to FE buckling.

Capesize, BC3, transverse bulkhead assessment results covering prescriptive and FE assessment are as follows:

- Bulkhead between empty and loaded hold; increase +0.5mm to +1.0mm on the plating is seen due to minimum thickness and GRAB.
- Bulkhead between loaded and ballast hold; increase +0.5mm to +1.0mm on the plating is seen due to minimum thickness and GRAB.

Handymax, BC10, transverse bulkhead assessment results covering prescriptive and FE assessment are as follows:

- Bulkhead between empty and loaded hold; increase of +1.5mm to +3.5mm on the plating is seen due to minimum thickness, local pressure and FE buckling.

6.9 Bulk Carriers – hull girder ultimate strength & residual strength

The hull girder ultimate strength results are summarised in table 12 below. Some scantling increases may be needed. This is due to the new γ_{db} factor (Ch.5, Sec.2, [2.1.2]). The Hull girder ultimate residual strength results were reviewed for bulk carriers and no scantling increase was seen.

Table 12: Bulk Carriers – Overview of hull girder ultimate strength and residual strength results (governing results are reported in the summary)

Hull Girder Ultimate Strength (HGUS)

Location	BC1	BC2	BC3	BC4	BC5	BC6	BC8	BC10
	Cape	Cape	Cape	Baby'C'	Baby'C'	P'max	H'max	H'max
Midship CH-EH	102.0%	103.0%	96.0%	76.9%	97.0%	94.0%	91.1%	90.7%
Midship CH-LH	101.0%	99.0%	86.0%	95.7%	100.0%	95.0%	N/A	96.2%
Midship CH-BH	102.9%	104.0%	85.0%	94.4%	99.0%	95.0%	N/A	N/A
Foremost cargo hold	OK	N/A	OK	OK	OK	OK	OK	OK
Aftmost cargo hold	OK	OK	OK	OK	OK	OK	OK	OK
Machinery Space	OK	OK	OK	OK	OK	OK	N/A	OK

Hull Girder Ultimate Residual Strength (HGURS)

Location	BC1	BC2	BC3	BC4	BC5	BC6	BC8	BC10
	Cape	Cape	Cape	Baby'C'	Baby'C'	P'max	H'max	H'max
Midship CH-EH/Grounding	79.7%	80.0%	72.0%	66.6%	76.0%	75.0%	69.3%	61.2%
Midship CH-LH/Grounding	73.3%	71.0%	66.0%	68.8%	73.0%	71.0%	N/A	64.0%
Midship CH-BH/Grounding	79.1%	78.0%	72.0%	72.5%	75.0%	73.0%	N/A	N/A
Midship CH-EH/Collision	69.5%	73.0%	65.0%	63.5%	76.0%	74.0%	93.3%	78.9%
Midship CH-LH/Collision	69.6%	73.0%	64.0%	76.5%	74.0%	82.0%	N/A	84.5%
Midship CH-BH/Collision	66.6%	73.0%	65.0%	75.5%	77.0%	85.0%	N/A	N/A
Foremost cargo hold	OK	N/A	OK	OK	OK	OK	OK	OK
Aftmost cargo hold	OK	OK	OK	OK	OK	OK	OK	OK
Machinery Space	OK	OK	OK	OK	OK	OK	N/A	OK

Percentage is calculated as: $M\gamma_R / M_u$ x 100; <100%: OK
Symbols are as used in the Rules Ch.5, Sec.2, [2.1.2].
Midship CH-EH: Empty Hold in alternate loading condition
Midship CH-LH: Loaded Hold in alternate loading condition
Midship CH-BH: Ballast Hold

6.10 Bulk Carriers – FE outside midship general summary

There is currently no finite element procedure in CSR covering the areas outside midship region. Impact analyses have been undertaken to identify any consequences on individual designs.

Table 13: Bulk Carriers – Overview of impact analyses for foremost and aftmost cargo hold finite element analyses

Bulk Carriers		Aftmost cargo hold		Foremost cargo hold	
		Yielding assessment	Buckling assessment	Yielding assessment	Buckling assessment
Capesize	BC1	Some increase is seen	Significant increase is seen	No results	
	BC2	Modest increase is seen	Significant increase is seen	No results	
	BC3	Modest increase is seen	Significant increase is seen	Modest increase is seen	Significant increase is seen
BabyCape	BC4	No increase is seen	Significant increase is seen	No increase is seen	Modest increase is seen
	BC5	Modest increase is seen	Significant increase is seen	Modest increase is seen	Modest increase is seen
Panamax	BC6	No increase is seen	Significant increase is seen	No increase is seen	Significant increase is seen
Handymax	BC8	No increase is seen	Significant increase is seen	No results	
	BC10	Modest impact is seen	Significant increase is seen	Modest impact is seen	Significant increase is seen

6.11 Bulk Carriers – local fine mesh

Results for fine mesh (yielding) structural strength analysis have been reviewed for the following ships.

- Capesize BC3; lower hopper connection and lower side frame connection in loaded hold indicates no scantling increase.
- Panamax BC6; side frame end brackets in loaded, empty, and ballast hold indicates no scantling increase.
- Handymax BC10; hopper knuckle analysis indicated that the transverse web will need increase to satisfy CSR-H.
- Handymax BC10; lower stool analysis indicated that the lower stool and floor will need increase to satisfy CSR-H.

6.12 Bulk Carriers – fatigue analysis by FE stress analysis

Results for fatigue analysis by finite element stress analysis have been reviewed for the following ships. Results are not calculated when the hot spot location is not required in CSR.

- Capesize BC1; lower hopper knuckle connection:

  Hot spot #1: Welded lower hopper knuckle connection (intersection of hopper sloping plate, inner bottom plate, longitudinal girder, floor and transverse web).
  Hot spot #2: Connections of transverse bulkhead lower stools to the inner bottom plating in way of double bottom girders.

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Hopper knuckle	Hot spot #1	43	27
Lower stool	Hot spot #2	65	47

- Babycape BC4; lower hopper knuckle connection:

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Hopper knuckle	Hot spot #1	35.3	53.6
	Hot spot #2	40.7	102.1
	Hot spot #3	160.3	>1000
	Hot spot #4	35.8	249.8
	Hot spot #5	81.5	>1000

- Babycape BC4; the connection between the lower stool and the inner bottom:

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Lower stool	Hot spot #1	71.5	25.5
	Hot spot #2	122.1	20.1
	Hot spot #3	338.1	946.6
	Hot spot #4	131.5	211.3
	Hot spot #5	>1000	>1000

- Handymax BC10; Loaded hold:

Location		Fatigue life in years CSR-H	Fatigue life in years CSR
Lower Hopper knuckle	Hot spot #1 (inn. btm.pl.)	21	68
	Hot spot #2 (slant pl.)	27	-
	Hot spot #3 (hopper web.pl.)	55	-
	Hot spot #4 (floor.pl.)	36	-
	Hot spot #5 (side girder.pl.)	65	-
	Hot spot #6 (Scarfing Bkt. toe)	121	-
Lower stool	Hot spot #1 (inn. btm.pl.)	28	29
	Hot spot #2 (low. stool pl.)	12	-
	Hot spot #3 (cent gir. hold)	22	-
	Hot spot #4 (cent gir. stool)	34	-
	Hot spot #5-1 (floor p-side)	32	-
	Hot spot #5-2 (floor s-side)	31	-

6.13 Bulk Carriers – local fine mesh structural strength analysis – Screening

Results of CSR-H for local fine mesh structural strength analysis for screening have been reviewed for the following ship.

- Capesize BC1 – screening No.N cargo hold

Location *Type of detail*	Screening factor λ_{sc}	Permissible screening factor λ_{scperm}
Connections of corrugation to adjoining structure(S)	1.13	1.20
Connections of corrugation to adjoining structure(S+D)	1.28	1.50
Notes: *Type of detail*, λ_{sc}, λ_{scperm}, is with reference to Ch 7, Sec 3, [3.3.1], Table 4.		

- Capesize BC3 – screening midship cargo hold (loaded)

Location *Type of detail*	Screening factor λ_{sc}	Permissible screening factor λ_{scperm}
Hatch Corner Area	0.963 (Max.)	0.95
Connections of transverse lower stool to double bottom girders	0.734 (Max.)	0.75
Connections of lower hopper to transverse lower stool structure	0.773 (Max.)	0.75
Connections of corrugation and upper supporting structure to upper stool	0.540 (Max.)	0.60
Notes: *Type of detail*, λ_{sc}, λ_{scperm}, is with reference to Ch 7, Sec 3, [3.3.1], Table 4.		

- Capesize BC3 – screening No.1 cargo hold

Location *Type of detail*	Screening factor λ_{sc}	Permissible screening factor λ_{scperm}
Connections of Corrugation to Adjoining Structure (S+D)	3.469 (Max.)	1.8
Connections of Corrugation to Adjoining Structure (S)	0.976 (Max.)	1.44
Notes: *Type of detail*, λ_{sc}, λ_{scperm}, is with reference to Ch 7, Sec 3, [3.3.1], Table 4.		

- Handymax BC10 – screening midship cargo hold (empty)

Location *Type of detail*		Screening factor λ_{sc}	Permissible screening factor λ_{scperm}
Connections of lower stool to double bottom girders	Centre girder	0.84	0.6
Connection of lower hopper to transverse lower stool	Lower stool	0.70	0.75
Connection of Corrugation and upper supporting structure to upper stool	Corr. BHD	0.75	0.675
Hatch corner area	Topside plate	0.89	0.95
Notes: *Type of detail*, λ_{sc}, λ_{scperm}, is with reference to Ch 7, Sec 3, [3.3.1], Table 4.			

- Handymax BC10 – screening midship cargo hold (loaded)

Location *Type of detail*		Screening factor λ_{sc}	Permissible screening factor λ_{scperm}
Connections of lower stool to double bottom girders	Centre Girder	1.01	0.75
Connection of lower hopper to transverse lower stool	Bilge Hopper	0.94	0.75
Connection of Corrugation and upper supporting structure to upper stool	Corr. BHD	0.82	0.675
Hatch corner area	Topside Plate	0.67	0.76
Notes: *Type of detail*, λ_{sc}, λ_{scperm}, is with reference to Ch 7, Sec 3, [3.3.1], Table 4.			

- Handymax BC10 – screening No.1 cargo hold

Location *Type of detail*		Screening factor λ_{sc}	Permissible screening factor λ_{scperm}
Connections of lower stool to double bottom girders	Bottom girder	1.66	0.75
Connection of lower hopper to transverse lower stool	Bilge hopper	0.93	0.75
Connection of Corrugation and upper supporting structure to upper stool	Corr. BHD	0.51	0.75
Hatch corner area	Topside plate	0.43	0.6
Hopper knuckle	Bilge hopper	1.77	1.5
Side frame end bracket	Bilge hopper	2.01	1.5
Connection of corrugation to adjoining lower structure	Lower stool	1.43	1.5
Notes: *Type of detail*, λ_{sc}, λ_{scperm}, is with reference to Ch 7, Sec 3, [3.3.1], Table 4.			

- Handymax BC10 – screening No.N cargo hold

Location *Type of detail*		Screening factor λ_{sc}	Permissible screening factor λ_{scperm}
Connections of lower stool to double bottom girders	Bottom girder	0.68	0.6
Connection of lower hopper to transverse lower stool	Bilge hopper	0.56	0.6
Connection of Corrugation and upper supporting structure to upper stool	Corr. BHD	0.46	0.75
Hatch corner area	Topside plate	0.82	0.95
Hopper knuckle	Bilge hopper	1.18	1.2
Side frame end bracket	Bilge hopper	1.71	1.5
Connection of corrugation to adjoining lower structure	Lower stool	1.65	1.5
Notes: *Type of detail*, λ_{sc}, λ_{scperm}, is with reference to Ch 7, Sec 3, [3.3.1], Table 4.			

7 Appendix A - Glossary

The figures and tables in this document use the nomenclature defined below.

Strakes

The approximate strake positions have been indicated in order to show appropriate detail for representative plate thickness and ***adjacent*** stiffener scantlings. Exact stiffener groupings have not been shown to protect design confidentiality.

Structure identification labels

The following acronyms have been used to identify the various structural elements:

BG	Bottom Girder
BLG	Bilge
BTM	Bottom Shell
IB	Inner Bottom
IH	Inner Hull
HPR	Hopper Plate
LL	Longitudinal Bulkhead
LS	Lower Stool
MD	Main Deck
SS	Side Shell
ST	Stringer
TB	Transverse Bulkhead
TW	Transverse Web
US	Upper Stool
TST	Top Side Tank
COT	Cargo Oil Tank
CH	Cargo Hold

Load identification labels

The following acronyms have been used to identify the various loads:

Ext	External pressures acting on shell or deck
BWT	Water ballast pressure
Bulk-AH	Dry bulk /Heavy alternate loading condition
Bulk-HH	Dry bulk /Heavy homogeneous loading condition
Bulk-H	Dry bulk /Homogeneous loading condition
Bulk-AVD	Dry bulk / Alternate loading condition with virtual density MHD/VH
Oil	Oil cargo pressure
HFO	Heavy fuel oil pressure
TK	Other tank pressure
Coil	Steel coil loading
Slosh	Sloshing pressure
Impact	Bottom slamming, bow flare impact
Grab	Grab loading

Load case identification labels

The following acronyms have been used to identify the various dynamic load cases:

HSM-1
HSM-2
OSA-2S

Draught identification labels

TSC	Scantling Draught
TNB	Normal Ballast Draught
THB	Heavy Ballast Draught
TXX	Reduced draught of XX% from TSC (i.e. T67 for BC multi port condition)

Numbering system
In general the strakes and girders are numbered from the centre line outward and from the baseline upward. The stringers are numbered from the upper to the lower.

Stiffener types
The following identification is used:

FB Flat Bar
BP Bulb Plate
IA Inverted Angle
T tee section

Materials
The following symbols are used:

MS Mild Steel of yield stress = 235 N/mm^2
H32 High Tensile Steel of yield stress = 315 N/mm^2
H36 High Tensile Steel of yield stress = 355 N/mm^2

CSR or CSR-H Required
The plating in mm and the stiffener size in cm^3. In the case of required columns, the thickness or section modulus necessary to comply with the Rules is indicated.

Scantling change
The incremental change for plating is shown in mm. For plating the following is indicated in the detailed results in the Appendices:

- Difference in net CSRH - CSR in mm
- Difference in net CSRH – offered net thickness in mm

For Rule to Rule comparison, the difference is calculated for yield results only, buckling is not indicated in the difference columns.
For Rules to offered scantling comparison, the difference is calculated for both yielding and buckling.
The change for stiffeners is shown as the percentage change in section modulus. For stiffeners the following is indicated:

- Percentage difference between CSR and CSRH. Percentage calculated as (CSRH – CSR) / CSR.
- Percentage difference between offered stiffener modulus and CSRH. Percentage calculated as (CSRH – offered) / offered.

For Rule to Rule comparison, the percentages are calculated for yield results only, buckling is not indicated in the percentage columns.
For Rules to offered scantling comparison, the difference is calculated for both yielding and buckling.

Criterion

The following shorthand is used to identify the criterion driving the scantlings:

CSR Tanker

Short description	Rule category	CSR Tanker Rule reference
HG Bending	Hull girder bending requirement	8/1.2
HG Shear	Hull girder shear	8/1.3
HG Initial Buckling	Hull girder initial/prescriptive buckling	8/1.4.2 & 10/3
HG US	Hull girder ultimate strength	9/1
Local, Min T	Local scantling, minimum thickness	8/2.1.5, 8/2.1.6, 8/3.1.4, 8/4.1.5 & 8/5.1.4
Local, press	Local scantling, loads based	8/2 Table 8.2.4 to 8.2.8, 8/3.9, 8/4.8 & 8/5.1.2
Local, press	Local scantling, loads based	8/2.6 for PSM
Local, press	Local scantling, loads based	8/2.5.6 & 2.5.7 for corrugations
Local, Other	Local Scantling misc. empirical formulae	Other Req. except Rule Ref. for Local, Min T and Local, press
Sloshing	Local scantling, sloshing	8/6.2
Bottom Slam	Local scantling bottom slamming forward	8/6.3
Bow Impact	Local scantling bow Impact forward	8/6.4
Buckling slender	Buckling according to stiffness and proportions	10/2.2
PSM Buckling pres	Prescriptive buckling for PSM	10/2.3 except 10/2.3.3
Quay	Local Scantling quay requirement	8/2.2.4
FEM Yield	FEM yielding criteria	9/2 Table 9.2.1
FEM buckling	FEM advanced buckling criteria	9/2 Table 9.2.2
HG Fatigue	HG section modulus increase for fatigue	8/1.5
Local, fatigue	Local fatigue for stiffener end connections	9/3 and App C

CSR BC

Short description	Rule category	CSR BC Rule reference
HG Bending	Hull girder bending requirement	Ch 5,Sec 1,2.1
HG Shear	Hull girder shear	Ch 5,Sec 1,2.2
HG Buckling	Hull girder prescriptive buckling	Ch 6,Sec 3
HG US	Hull girder ultimate strength	Ch 5,Sec 2
Local, Min T	Local scantling, minimum thickness	Ch 6,Sec 1, Ch 9, Sec 1, Sec 2, Sec 3
Local, press	Local scantling, loads based	Ch 6,Sec 1, Sec 2, Ch 9, Sec 1, Sec 2, Sec 3, Sec 4, Sec 5
Local, press	Local scantling, loads based	Ch 6, Sec 4, Sec 2, Sec 4 for PSM
Local, press	Local scantling, loads based	Ch 6, Sec 2, 3.3, Sec 2,3.6 for corrugations
Local, press	Local scantling, loads based	Ch 6, Sec 2, 3.3 for side frames
Bottom Slam	Local scantling bottom slamming forward	Ch 9, Sec 1, 5
Bow Impact	Local scantling bow Impact forward	Ch 9, Sec 1, 4
Buckling slender	Buckling according to stiffness and proportions	Ch 3, Sec 6, 5.2, Ch 6, Sec 2, 2
PSM Buckling pres	Prescriptive buckling for PSM	Ch 3, Sec 6, 5…?
FEM Yield	FEM yielding criteria	Ch 7, Sec 2, 3.2
FEM buckling	FEM advanced buckling criteria	Ch 7, Sec 2, 3.3
FEM deflection	FEM advanced deflection criteria	Ch 7, Sec 2, 3.4
Local, fatigue	Local fatigue for stiffener end connections	Ch 8, Sec 4
Steel Coil	Steel coil loading	Ch 6, Sec 1, 2.7
Grab	Grab loading	Ch 12, Sec 1

CSR-H Rule reference

Short description	**Rule category**	**CSR-H Rule reference**
HG Bending	Hull girder bending requirement	Pt 1, Ch 5, Sec 1
HG Shear	Hull girder shear	Pt 1, Ch 5, Sec 1
HG Buckling	Hull girder prescriptive buckling	Pt 1, Ch 8, Sec 3
HG US	Hull girder ultimate strength	Pt 1, Ch 5, Sec 2
Local, Min T	Local scantling, minimum thickness	Pt 1, Ch 6, Sec 3
Local, press	Local scantling, loads based	Pt 1, Ch 6, Sec 4 or 5
Bottom Slam	Local scantling bottom slamming forward	Pt 1, Ch 10, Sec 1
Bow Impact	Local scantling bow Impact forward	Pt 1, Ch 10, Sec 1
Buckling slender	Buckling according to stiffness and proportions	Pt 1, Ch 8, Sec 2
PSM Buckling pres	Prescriptive buckling for PSM	Pt 1, Ch 8, Sec 3
FEM Yield	FEM yielding criteria	Pt 1, Ch 7, Sec 2
FEM buckling	FEM advanced buckling criteria	Pt 1, Ch 8, Sec 4
FEM deflection	FEM advanced deflection criteria	
Local, fatigue	Local fatigue for stiffener end connections	Pt 1, Ch 9, Sec 3
Steel coil	Steel coil loading	Pt 2, Ch 1, Sec 3
Grab	Grab loading	Pt 2, Ch 1, Sec 6