IACS Common Structural Rules for Double Hull Oil Tankers, January 2006

Background Document

SECTION 8/2 – SCANTLING REQUIREMENTS CARGO TANK REGION

NOTE:

- This TB is published to improve the transparency of CSRs and increase the understanding of CSRs in the industry.
- The content of the TB is not to be considered as requirements.
- This TB cannot be used to avoid any requirements in CSRs, and in cases where this TB deviates from the Rules, the Rules have precedence.
- This TB provides the background for the first version (January 2006) of the CSRs, and is not subject to maintenance.

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2.1 General

2.1.1 Application

2.1.1.a "Cargo tank region" is specified to exclude void spaces and the pump room aft of the aftermost cargo tanks and forward of foremost cargo tanks from application of the criteria.

2.1.2 Basis of scantlings

2.1.2.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background

2.1.3 Evaluation of scantlings

2.1.3.a The general notes in *Section 8/2.1.3.1 of the Rules* are introduced based on the paragraph in ABS Rules Pt.5 Ch.1 Sec.4/1.5.

2.1.3.b The general notes in *Section 8/2.1.3.2 of the Rules* that the strength criteria are to be satisfied at all longitudinal positions is provided to cover variations of the requirements due to different locations and tank configurations.

2.1.3.c The general notes in *Section 8/2.1.3.3 of the Rules* are provided to cover local variations of local loads, stiffener spacing and stiffener spans.

2.1.4 General scantling requirements

2.1.4.a It is considered that for *Section 8/2.1.4.1 through 2.1.4.5* of the *Rules*, no information in addition to that shown in the Rules is necessary to explain the background.

2.1.4.b The requirements of *Section 8/2.1.4.6 of the Rules* are based on LR Rules Pt 4, Ch 1,8.2.9.

2.1.4.c The requirements of *Section 8/2.1.4.7 of the Rules* are based on LR Rules Pt 4, Ch 9,6.7.2.

2.1.5 Minimum thickness for plating and local support members

2.1.5.a The requirements are derived by combination of the existing rule requirements of ABS, DNV and LR but adjusted for the corrosion addition. Correction for the higher strength materials is not applied since these requirements are not stress based requirements but absolute minimum thickness requirements, which cover general robustness, corrosion and durability issues. The requirements are based upon a detailed study carried out by ABS, DNV and LR.

2.1.6 Minimum thickness for primary support members

2.1.6.a The requirements are derived by combination of the existing rule requirements of ABS, DNV and LR but adjusted for the corrosion addition. Correction for the higher strength materials is not applied since these requirements are not stress based requirements but absolute minimum thickness requirements, which cover general robustness, corrosion and durability issues. The requirements are based upon a detailed study carried out by ABS, DNV and LR.

2.2 Hull Envelope Plating

Table 8.2.4 of the *Rules* includes the general plate thickness requirement formula. The general format and procedure are similar to IACS Common Structural Rules for Bulk Carriers. The "Permissible Bending Stress Coefficients for Plating" (C_a Factor) are based on an extensive study carried out by ABS, DNV and LR. The individual plating requirements refer to these tables and also include any additional requirements to consider.

2.2.1 Keel plating

2.2.1.a The requirements of *Section 8/2.2.1.1* of the *Rules* are based on ABS Rules 5-1-4/7.1.2, DNV Rules Pt.3 Ch.1 Sec.6 C200 and LR Rules Pt 4, Ch 4,9.4.7, Table 9.4.1.

2.2.1.b It is considered that for *Section 8/2.2.1.2* of the *Rules* this topic, no information in addition to that shown in the Rules is necessary to explain the background.

2.2.2 Bottom shell plating

2.2.2.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

2.2.3 Bilge plating

2.2.3.a The requirements of *Section 8/2.2.3.1* of the *Rules* are based on DNV Rules Pt.3 Ch.1 Sec.6 C306 and ABS Rules Pt.5 Ch.1 Sec.4/7.3.1.

2.2.3.b The requirements of *Section 8/2.2.3.2* of the *Rules* are based on the curved panel buckling against external lateral pressure in accordance with DNV Rules Pt.3 Ch.1 Sec.6 C307. The coefficient in the formula has been adjusted for the net scantlings. The requirements are based upon a detailed study carried out by ABS, DNV and LR. A “Note” that bilge keel is not considered as “longitudinal stiffening” for the application of this requirement is added.

2.2.3.c The requirement is based on LR Rules Pt 4, Ch 9,4.6.3.

2.2.4 Side shell plating

2.2.4.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

2.2.4.b The requirements are based on fender contact requirements in accordance with DNV Rules Pt.3 Ch.1 Sec.7 C103. The coefficient in the formula has been adjusted for the net scantlings.

2.2.4.c For the applicable extent of the fender contact requirement “300mm below the lowest ballast waterline amidships” is added to avoid a problem when the ballast waterline moves or to absorb the possible difference of ballast waterline between the initial design stage and the final one.

2.2.5 Sheer strake

2.2.5.a It is considered that for *Section 8/2.2.5.1* of the *Rules*, no information in addition to that shown in the Rules is necessary to explain the background.

2.2.5.b The requirements of *Sections 8/2.2.5.2 and 2.2.5.3* of the *Rules* are based on DNV Rules Pt.3 Ch.1 Sec.7 C206 and C207, respectively.

2.2.6 Deck plating

2.2.6.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

2.3 Hull Envelope Framing

2.3.1 General

2.3.1.a *Tables 8.2.5* and *8.2.6* of the *Rules* include the general section modulus and stiffener web shear requirement formulas, respectively. The general format and procedure are similar to IACS Common Structural Rules for Bulk Carriers. The "Permissible Bending Stress Factor Coefficients for Stiffeners" (C_s Factor) and "Permissible Shear Stress Factor" (C_t Factor) are based on an extensive study carried out by ABS, DNV and LR. The individual section modulus and shear requirements refer to these tables and also include any additional requirements to consider.

2.3.1.b The requirements of *Section 8/2.3.1.1* of the *Rules* are based on LR Rules Pt 4, Ch 9,1.3.10 to 1.3.12.

2.3.1.c The requirements of *Section 8/2.3.1.2* of the *Rules* are based on DNV Rules Pt.3 Ch.1 Sec.6 C307, C705 and LR Rules Pt 4, Ch 9,5.4.2. The ratio "40 times the local shell thickness" has been adjusted to "50 times the local shell thickness" for the net thickness as shown in *Table 8.2.a*.

Table 8.2.a
The local shell thickness ratio

Ship		**HANDY**	**AFRAMAX**	**SUEZMAX**	**VLCC1**	**VLCC2**	
Side long'l space	mm	650	670	910	840	950	
Btm long'l space	mm	800	685	880	850	910	
Bilge Radius	mm	1700	1900	2400	2600	2400	
Bilge Radius/3	mm	**567**	**633**	**800**	**867**	**800**	
Target *t* Gross	mm	16	19	19.5	22	20	
Target *t* Gross x 40	mm	640	760	780	880	800	
Target *t* Net	mm	**12**	**15**	**15.5**	**18**	**16**	
Target *t* Net x 40	mm	480	600	620	720	640	
As built gross	mm	15	19	17.5	20	20	
As built gross x 40	mm	600	760	700	800	800	**mean**
$40t_{ab}/t_{target\text{-}net}$	mm	**50**	**51**	**45**	**44**	**50**	**48**
$50t_{target\text{-}net}$	mm	600	750	775	900	800	**use 50**

2.3.2 Scantling criteria

2.3.2.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

2.4 Inner Bottom

2.4.1 Inner bottom plating

2.4.1.a It is considered that for *Section 8/2.4.1.1* of the *Rules*, no information in addition to that shown in the Rules is necessary to explain the background.

2.4.1.b The requirements of *Section 8/2.4.1.2* of the *Rules* are based on LR Rules Pt 4, Ch 9,6.5.4 and 6.6.3 but rephrased generally in light of possible alternative design other than built up connection.

2.4.1.c The requirements of *Section 8/2.4.1.3* of the *Rules* are based on LR Rules Pt 4, Ch 9,6.5.5.

2.4.2 Inner bottom longitudinals

2.4.2.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

2.5 Bulkheads

2.5.1 General

2.5.1.a The requirements of *Section 8/2.5.1.1* of the *Rules* are based on LR Rules Pt 4, Ch 9,1.3.1 and 6.1.1.

2.5.1.b The requirements of *Section 8/2.5.1.2* of the *Rules* are based on LR Rules Pt 4, Ch 9,6.3.6.

2.5.2 Longitudinal tank boundary bulkhead plating

2.5.2.a It is considered that for *Section 8/2.5.2.1* of the *Rules*, no information in addition to that shown in the Rules is necessary to explain the background.

2.5.2.b The requirements of *Section 8/2.5.2.2* of the *Rules* are based on LR Rules Pt 4, Ch 9,6.3.1.

2.5.3 Hopper side structure

2.5.3.a The requirements of *Section 8/2.5.3.1* of the *Rules* are based on LR Rules Pt 4, Ch 9,6.6.4.

2.5.4 Transverse tank boundary bulkhead plating

2.5.4.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

2.5.5 Tank boundary bulkhead stiffeners

2.5.5.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

2.5.6 Corrugated bulkheads in cargo tanks

2.5.6.a The requirements of *Section 8/2.5.6* of the *Rules* apply to vertically corrugated and horizontally corrugated bulkheads. The scantling requirements in *Sections 8/2.5.6* and *2.5.7* of the *Rules* are net requirements based on full corrosion additions, as local strength is critical to overall strength corrugated bulkhead.

2.5.6.b The requirements of corrugation angle contained in *Section 8/2.5.6.2* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/17.1 with slight modification of minimum limit of corrugation angle from 60 degrees to 55 degrees.

2.5.6.c *Section 8/2.5.6.3* of the *Rules* specifies that the global strength of corrugated bulkheads is to be verified by Finite Element Method. For corrugated bulkheads outside of midship region are to be considered based on the results from the Finite Element Analysis in midship region, using the appropriate pressure for the location under consideration. This is common to the existing Rule requirements of ABS, DNV and LR.

2.5.6.d The formula in *Section 8/2.5.6.4* of the *Rules* is the general plate thickness requirement formula as contained in *Table 8.2.4* of the *Rules*. Corrugated bulkhead may have significant in plane stresses (uni-axial in the direction of the corrugation). In addition, corrugated bulkhead has less redundancy than plane bulkhead where loads may be redistributed by membrane stresses in case of local failure. A local failure at lower end or corrugation mid-span will in most cased result in a total collapse of the bulkhead. Hence permissible bending stress coefficients for corrugated bulkhead (C_a Factor) are set at slightly lower values than that for plane bulkhead.

2.5.6.e The formula in *Section 8/2.5.6.5 of the Rules* is based on DNV Rules Pt.3 Ch.1 Sec.9/C101.

2.5.7 Vertically corrugated bulkheads

2.5.7.a It is considered that for *Section 8/2.5.7.1* of the *Rules*, no information in addition to that shown in the Rules is necessary to explain the background.

2.5.7.b The requirements of *Section 8/2.5.7.2* of the *Rules* are based on the ABS Rules Pt.5 Ch.1 Sec.4/17.3. Similar requirements are also contained in IACS UR S18.4.1.

2.5.7.c The requirements of *Section 8/2.5.7.3* of the *Rules* address shear strength, they are based on ABS Rules Pt.5 Ch.1 Sec.4/17.3. The shear force is only a concern over the lower portion of the bulkhead, so the application requirements are limited to the lower 15 percent of the corrugated bulkhead depth, consistent with the application of similar requirements in IACS UR S18. The requirements in this *Sub-section* are not applicable to corrugated bulkheads without a lower stool.

2.5.7.d The requirements of *Section 8/2.5.7.4* of the *Rules* are based on the ABS Rules Pt.5 Ch.1 Sec.4/17.5.1 and provide a minimum stiffness requirement.

2.5.7.e The requirements of *Section 8/2.5.7.5* of the *Rules* are based on the ABS Rules Pt.5 Ch.1 Sec.4/17.3. The formula for thickness in the Rules is based on calculations that are performed to check the buckling strength of the corrugated bulkhead. This is a local buckling strength criterion for the corrugation flange, which determines the overall buckling strength of the corrugation as a beam-column. The formulas in the Rules are based on results of experimental and theoretical work on buckling strength of corrugated bulkheads. Of particular note, the plate buckles as a result of lateral load and not because of in-plane compression. The requirements in this *Sub-section* are not applicable to corrugated bulkheads without a lower stool.

2.5.7.f The requirements are based on the ABS Rules Pt.5 Ch.1 Sec.4/17.5.2. The formula for required section modulus is based on simple beam theory and the basic understanding that the vertically corrugated bulkhead can be considered as consisting of separate vertically oriented beam-columns (i.e. corrugations) working independently. The loading on the corrugated bulkhead consists of the following three major components – (1) lateral pressure, (2) "carry over" bending moments due to bending of the double bottom, and (3) vertical axial force in the corrugation due to double bottom bending and loads on deck. The formulae explicitly consider the boundary conditions for the two corrugation ends, which are addressed in the formulations provided in *Table 8.2.3*. The requirements were calibrated against FEM calculations. The requirements in this *Sub-section* are not applicable to corrugated bulkheads without a lower stool.

2.5.7.g The requirements of *Section 8/2.5.7.7* of the *Rules* are based on DNV Rules Pt.3 Ch.1 Sec.4 C300. The sloshing pressure as given in *Section 7/4.2* of the *Rules* is not applicable for tanks with effective sloshing breadth, b_{slh}, greater than 0.56B or effective sloshing length, l_{slh}, greater than 0.13L for which an additional impact assessment is to be carried out in accordance with the individual Classification Society procedures.

2.5.7.h The requirements of *Section 8/2.5.7.8* of the *Rules* are based on the ABS Rules Pt.5 Ch.1 Sec.4/17.7.1 and *17.7.3*. However, restrictions on the geometry and size of the stools have been modified so that lower stool configurations are less restrictive, consistent with present practice. Similar requirements are also contained in UR S18.4.1.

2.5.7.i The requirements of *Section 8/2.5.7.9* of the *Rules* are for the arrangements without lower stools, which are allowed for ships with a moulded depth less than 16m. For such ships, the prescriptive requirements of corrugation web shear, flange buckling and section modulus requirements as given in *Sections 8/2.5.7.3, 8/2.5.7.5* and *8/2.5.7.6* are not applicable. On the other hand, bending, shear and buckling strength of the corrugation are to be assessed by Finite Element Analysis with reduced maximum permissible utilization factors (by 10%). In way of the connection of the corrugation to the double bottom structure, similar but more stringent requirements than that required for lower stool structure on ships with a lower stool are applied.

2.5.7.j The requirements of *Section 8/2.5.7.10* of the *Rules* are based on the ABS Rules Pt.5 Ch.1 Sec.4/17.7.2 and *17.7.3*. However, restriction explicit wording has been included to permit arrangements without upper stools, consistent with present practice. Similar requirements are also contained in IACS UR S18.4.1.

2.5.7.k The requirements of *Section 8/2.5.7.11* of the *Rules* are based on the ABS Rules Pt.5 Ch.1 Sec.4/17.9.

2.5.7.l It is considered that for *Section 8/2.5.7.11* of the *Rules*, no information in addition to that shown in the Rules is necessary to explain the background.

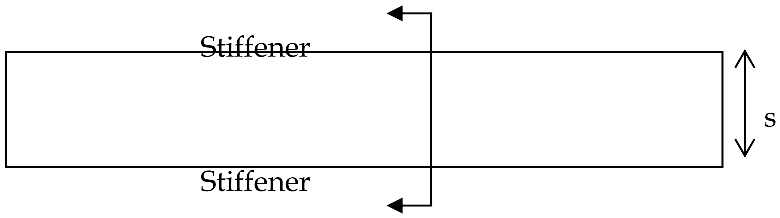
2.5.8 Non-tight bulkheads

2.5.8.a The requirements of *Section 8/2.5.8.1* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/15.13 with the omission of the limitation of the maximum aggregate area of openings of 33%.

Table 8.2.4 Thickness Requirements for Plating

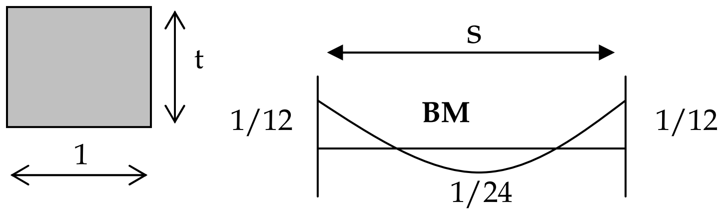
The net thickness formula was derived as below:

Plate panel surrounded by local/primary support members:



Considering a beam having section with a unit width (1) and depth of plate thickness, bending moment when the both ends are fixed are as follows:

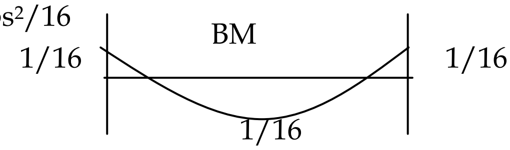
Section of the beam



Bending moment at both ends = $ps^2/12$

If the above model is further loaded until plastic hinges are created at the midspan and at the ends:

Moment at both ends and midspan = $ps^2/16$
Plastic SM = $t^2/4$



Assuming allowable stress

= $C_a \sigma_{yd}$= M/SM = $ps^2/(4t^2)$

Therefore,

$$t = \frac{s}{2}\sqrt{\frac{p}{C_a\,\sigma_{yd}}}$$

where,
s is in mm, p is in N/mm² and σ_{yd} is in N/mm

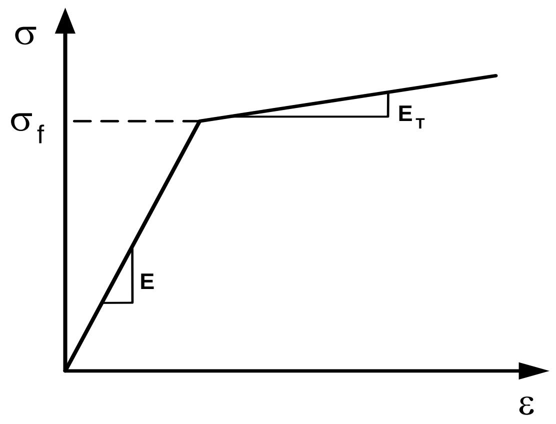
Converting the unit of p from N/mm² to kN/m²

$$t = \frac{s}{2\sqrt{1000}}\sqrt{\frac{p}{C_a\,\sigma_{yd}}} = 0.0158\,s\sqrt{\frac{p}{C_a\,\sigma_{yd}}}$$

The permissible bending stress factor (C_a) was determined based on extensive Non-linear Analysis as outlined below:

The material curve has a linear strain hardening of ET =1000N/mm² for stresses exceeding yield stress, σ_f., E=206000N/mm², ν=0.3

$$\sigma = E\varepsilon$$



Finite element models:

Plate thickness t (mm)	Length of plate, l (mm)	
	800	4800
10		HT32
13		MS, HT32, HT36
16	HT32	HT32

Summary analysis results:

- The results show that the bending strength of plates is particularly sensitive to transverse compression.
- Also longitudinal compression reduces the plate bending strength, but primarily when acting in combination with transverse compression.
- The evaluation of the results has mainly focused on the permanent plastic strain.

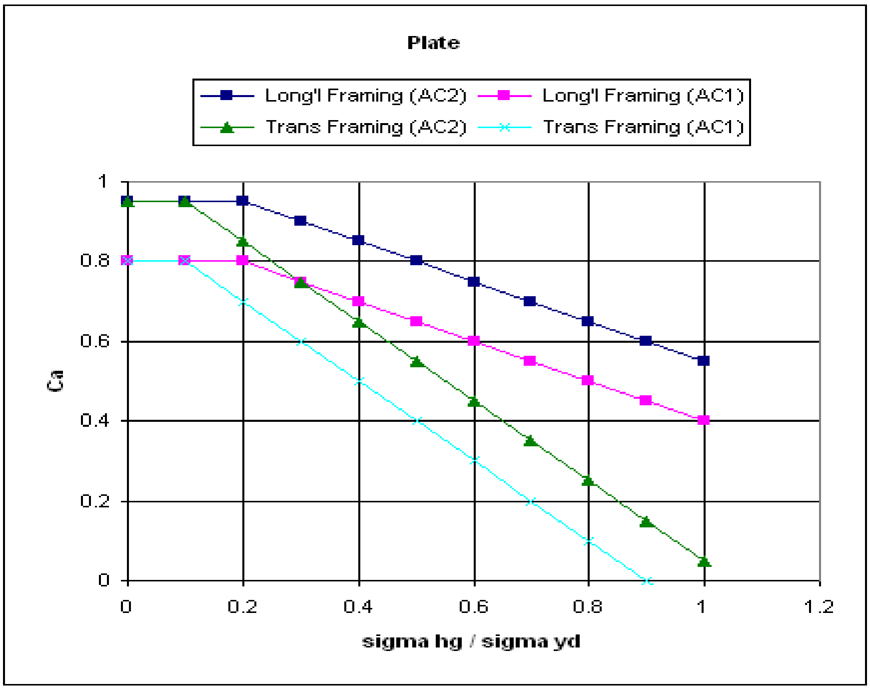
Benchmark giving permanent plastic strain upper limitations:

a) Load combination a (static loads, functional loads or loads with short return period)
2 times yield

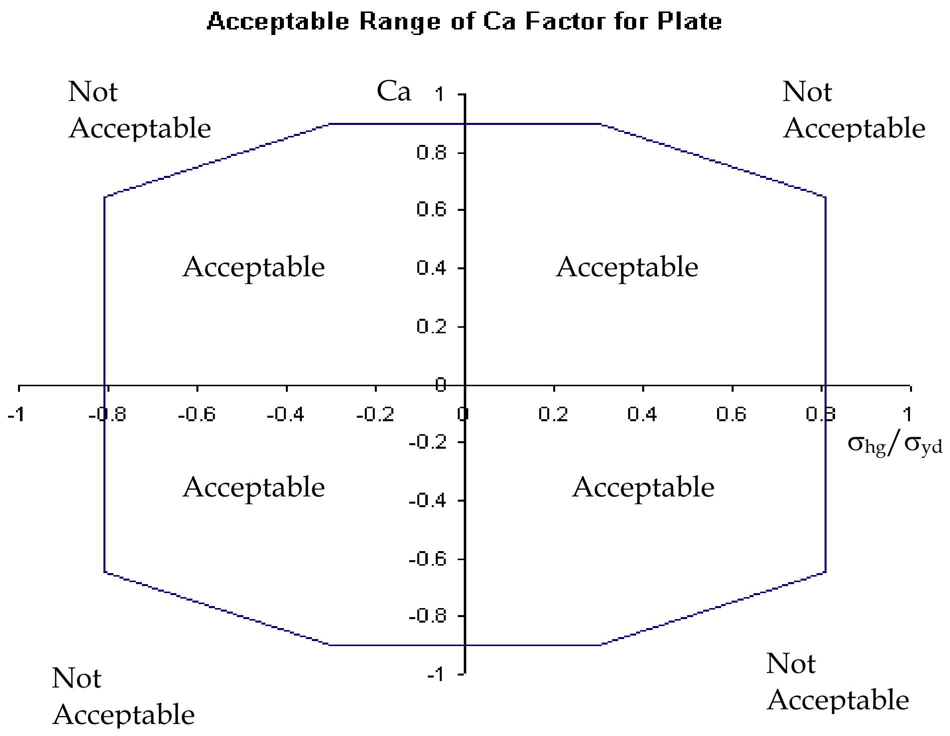
b) Load combination b (static loads and dynamic loads at 10^{-8} probability level)
4 times yield strain
The maximum strain value corresponds to a maximum permanent deformation of 0,004s

Based on the above analysis, the following permissible bending stress factors are determined:

Acceptance Criteria Set	Structural Member		β_a	α_a	C_{a-max}
AC1	Longitudinal Strength Members	Longitudinally stiffened plating	0.9	0.5	0.8
		Transversely or vertically stiffened plating	0.9	1.0	0.8
	Other members		0.8	0	0.8
AC2	Longitudinal Strength Members	Longitudinally stiffened plating	1.05	0.5	0.95
		Transversely or vertically stiffened plating	1.05	1.0	0.95
	Other members, including watertight boundary plating		1.0	0	1.0



For plating subjected to hull girder stresses, acceptance range for various combinations of hull girder stresses and local pressure based stresses are as follows:



The non-linear analysis was also carried out using a square plate panel. The results are in good agreement with the existing DNV formulation. Since the curve in the existing DNV formulation is nearly straight for s/l ratio between 0.4 and 1.0, the format of the equation is changed similar to that in the existing LR Rules.

ABS Rule $$k(ABS) = \frac{3.075\sqrt{\frac{\ell}{s}} - 2.077}{\frac{\ell}{s} + 0.272}, (\max 1.0)$$

DNV Rule $$k(DNV) = \left(1.1 - 0.25\frac{s}{\ell}\right)^2, (\max 1.0)$$ → **This curve used**

LR Rule $$k(LR) = 1.1 - 0.4\frac{s}{\ell}, (\max 1.0)$$ → **This format used**

CSR $$k(CSR) = 1.2 - \frac{s}{2100\ \ell}$$
$$\max .1.0, s(mm), \ell(m)$$

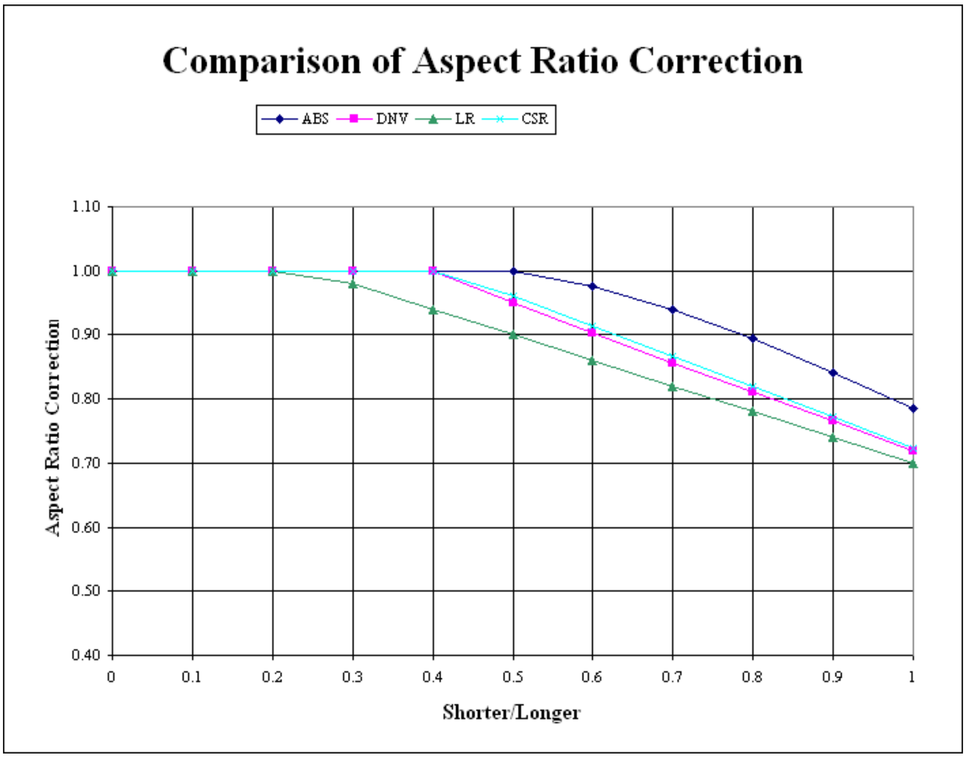

Comparison of Aspect Ratio Correction
ABS
DNV
LR
CSR
Aspect Ratio Correction
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Shorter/Longer

Table 8.2.5 Section modulus requirements for stiffeners

The stiffener section modulus formula given in *Table 8.2.5* of the *Rules* is based on general elastic beam theory with the both ends fixed in general. "m" for horizontal stiffeners of 12 is based on the bending moment at ends of $|P| s \, l_{bdg}^{2} / 12$ assuming uniform loading.

"m" for vertical stiffeners of 10 is based on the bending moment at lower end of $|P| s \, l_{bdg}^{2} / 10$ for linearly varying pressure distribution (higher loads at lower end of the stiffener) and also assuming certain degree of carry over bending moment transmitted from the adjacent lower stiffener.

Permissible bending stress factor (C_s):

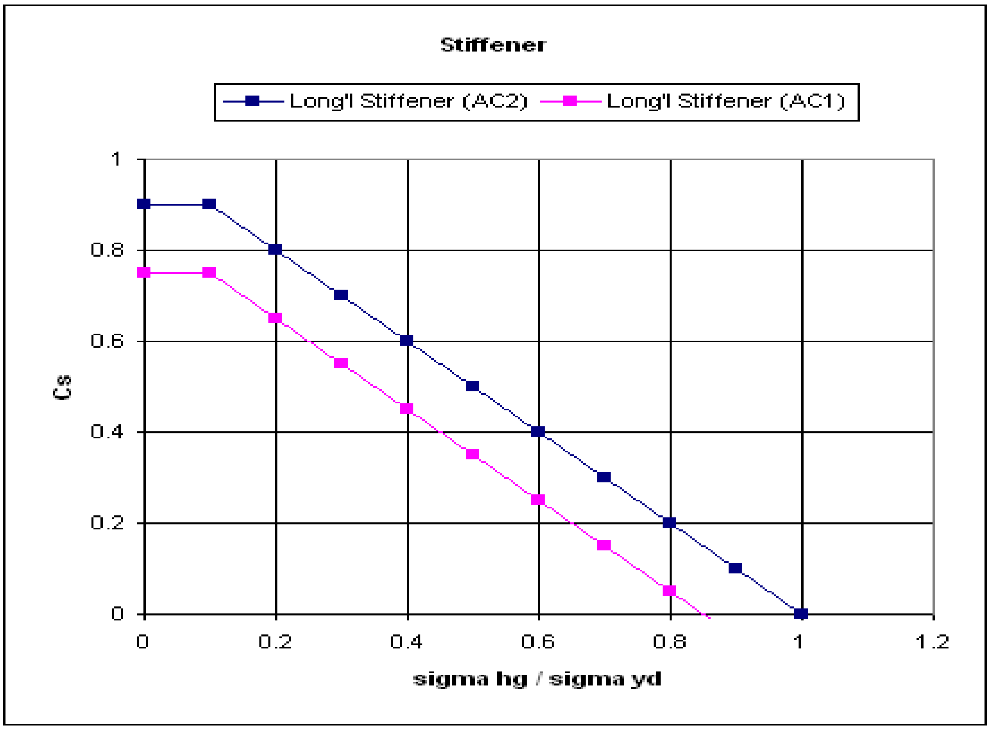
Permissible bending stress factor (C_s) for stiffener is to be considered in elastic range (unlike plate). The total permissible bending stress factor based on combined local pressure based stress and hull girder stress are basically set to be 1.0 for "Static+Dynamic" condition and 0.85 for "Static" condition respectively (with maximum limit of 0.9 and 0.75 respectively for local pressure only).

C_s factor for the member subjected to hull girder stresses:

For stiffeners subjected to hull girder stresses, acceptance criteria for various combinations of hull girder stresses and local pressure based stresses are as follows:

Sign of Hull Girder Bending Stress, σ_{hg}	Pressure acting on	Acceptance criteria
Tension (+ve)	Stiffener Side	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{\sigma_{yd}}$ but not to be taken greater than $C_{s\text{-}max}$
Compression (-ve)	Plate Side	
Tension (+ve)	Plate Side	$C_s = C_{s\text{-}max}$
Compression (-ve)	Stiffener Side	

Acceptance Criteria Set	Structural Member	β_s	α_s	$C_{s\text{-}max}$
AC1	Longitudinal strength member	0.85	1.0	0.75
	Transverse or vertical strength member	0.75	0	0.75
AC2	Longitudinal strength member	1.0	1.0	0.9
	Transverse or vertical strength member	0.9	0	0.9
	Watertight boundary Stiffeners	0.9	0	0.9



Where the member is subjected to hull girder stresses, the local pressure based stress is simply added on the hull girder stress. Where the directions of hull girder stress and local pressure based stress are different, the "net" total stress is to comply with the permissible limit with the exception that the local pressure based stress ratio itself should not exceed the maximum limit ($C_{s\text{-}max}$). Also, hull girder stress itself should not exceed the hull girder stress limit. Consequently, the permissible range is expressed as follows:

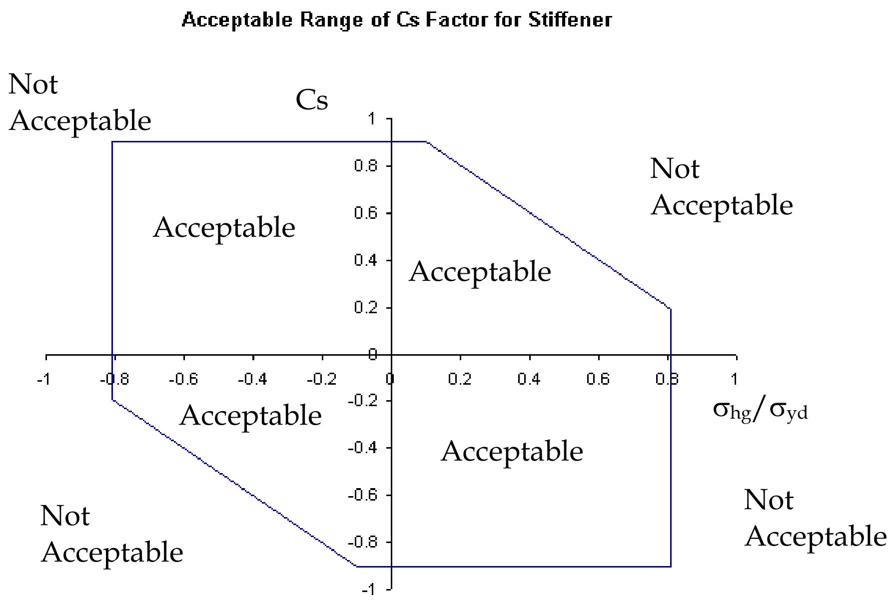


Table 8.2.6 Web thickness requirements for stiffeners

The formula given in *Table 8.2.6* of the *Rules* for stiffener web thickness is based on general elastic beam theory with the both ends fixed in general. "f_{shr}" for horizontal stiffeners of 0.5 is for the uniform pressure distribution. "f_{shr}" for vertical stiffeners of 0.7 is for the lower end of the stiffener with linearly varying pressure distribution.

The values of permissible shear stress factor (C_t) of 0.75 for AC1 and 0.9 for AC2 are consistent with the values of permissible bending stress factors (C_s) not subjected to hull girder stresses.

Table 8.2.7 Design Load Sets for Plating and Local Support Members given in Table 8.2.8

In general, maximum pressure of two sides of the boundary is to be used except for bottom and side shell for which "net" pressure difference between water ballast pressure and sea pressure is to be used.

For bottom and side shell in static condition (Design Load Set 8), $0.25T_{sc}$ is to be used for the net pressure difference of internal ballast pressure and external sea pressure irrespective of vessel configuration. (This draught is different from the draught used for double bottom floors and girders in accordance with *Table 8.2.9* of the *Rul*es)

Table 8.2.8 Specification of Design Load Combination, Acceptance Criteria and other Load Parameters for each Design Load Set

This table specifies the details of 16 Design Load Sets used for evaluation of plating, local support members and primary support members in *Tables 8.2.7* and *8.2.9* of the *Rules*. Load Scenario and Acceptance Criteria Sets (AC1, AC2 and AC3) are specified in *Section 2/7.3* and *7.4* of the *Rules*.

2.6 Primary Support Members

2.6.1 General

2.6.1.a It is considered that for *Section 8/2.6.1.1* to *2.6.1.3, 2.6.1.5* and *2.6.1.6* of the *Rules*, no information in addition to that shown in the Rules is necessary to explain the background.

2.6.1.b *Section 8/2.6.1.2 of the Rules* specifies the structural elements/configurations covered by the requirements for primary support members contained in *Section 8/2.6 of the Rules*. For other structural elements/configurations, the required scantlings are to be obtained by the calculation methods as described in *Section 8/7 of the Rules*. Typical structural elements to be calculated in accordance with *Section 8/7 of the Rules* are deck transverses fitted above the upper deck and horizontal stringers on transverse bulkheads fitted with buttresses or other intermediate supports, etc.

2.6.1.c The permissible reduction of the prescriptive requirements based on strength assessment (FEA) as indicated in *Section 8/2.6.1.4* of the *Rules* is in accordance with ABS Rules Pt.5 Ch.1 Sec.4/7.1 and 11.1. This reduction is meant to apply to section modulus and/or shear area and/or cross sectional area of a primary support member cross tie only, and not meant to apply to other requirements, e.g. minimum thickness.

2.6.1.d The requirements of of *Section 8/2.6.1.7* of the *Rules* are based on LR Rules Pt 4, Ch 9,10.3.1 and ABS Rules Pt.5 Ch.1 Sec.4/11.11. Lesser depths may be accepted where equivalent stiffness is demonstrated in accordance with *Section 3/5.3.3.4* of the *Rules.*

2.6.2 Design load sets and permissible stress factors for primary support members

2.6.2.a The draught used in *Table 8.2.9* of the *Rules* are generally in line with the loading conditions used in the strength assessment (FEA) as given in *Appendix B of the Rules.*

2.6.2.b For static plus dynamic cargo pressure in seagoing condition (AC2), partial load condition with a draught at $0.6T_{sc}$ is used to maximise the cargo pressure as this produces higher acceleration than full load condition except that for cross ties in wing cargo tanks, full load condition with the draught at $1.0T_{sc}$ is also used to synchronise with the maximum sea pressure case at draught at $1.0T_{sc}$.

2.6.2.c For static plus dynamic sea pressure in seagoing condition (AC2), the draught at $0.9T_{sc}$ is used for the double bottom floors and girders and side transverses considering the less probability of loading up to full draught with the cargo tank empty. However, if a ship is intended to be operated in seagoing loading condition where the net static upward load on the double bottom exceeds that given with the combination of an empty cargo tank and a mean ship's draught of $0.9T_{sc}$, such conditions are to be specially approved. For deck transverse, the draught at $1.0T_{sc}$ is used to maximise the green sea pressure.

2.6.2.d For static sea pressure in full load condition (AC1), the draught at $1.0T_{sc}$ is used to have the envelope value. It is considered appropriate to use the envelop value in static condition.

2.6.2.e For static sea pressure in harbour or tank test condition (AC1), the draught at $0.25T_{sc}$ (for ships with one centreline longitudinal bulkhead) or $0.33T_{sc}$ (for ships with two inner longitudinal bulkheads) is used to calculate the "net" pressure difference between the internal and external pressures for evaluation of double bottom floors and girders.

2.6.2.f In *Table 8.2.10* of the *Rules*, the permissible stress factors are determined in light of the permissible stress factors for primary support members in the existing ABS, DNV and LR Rules and also taking into account the net thicknesses.

2.6.3 Floors and girders in double bottom

2.6.3.a The requirements of *Section 8/2.6.3.1* of the *Rules* is based on LR Rules Pt 4, Ch 9,9.3.1.

2.6.3.b The requirements of *Section 8/*2.6.3.2 of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/7.7.3. The shear force distribution factors in *Table 8.2.11* of the *Rules* have been adjusted based on the calibration with the sample ships. Also, the shear span of the floor, where the floor ends on a girder at a hopper or stool structure, has been slightly modified.

2.6.3.c The requirements of *Section 8/2.6.3.3* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/7.7.1. The definition of the effective shear span of the floor, where the floor ends on a girder at a hopper or stool structure, has been slightly modified.

2.6.3.d The requirements of *Section 8/2.6.3.4* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/7.7.2. The definition of the effective shear span of the floor, where the floor ends on a girder at a hopper or stool structure, has been slightly modified.

2.6.4 Deck transverses

2.6.4.a The requirements of the web depth of deck transverses indicated in *Section 8/* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/11.11. The criteria have been slightly modified from the source ABS criteria based on the calibration with the sample ships approved by LR and DNV.

2.6.4.b It is considered that for *Section 8/2.6.4.2* of the *Rules*, no information in addition to that shown in the Rules is necessary to explain the background.

2.6.4.c The requirements of section modulus of deck transverses indicated in *Section 8/* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/11.3 with slight modifications. c_{st} and c_{vw} factors in *Table 8.2.12* of the *Rules* have been adjusted based on the calibration with the sample ships. Additional section modulus requirement for green sea load has been introduced. Since the phasing between the maximum sea load imposed on the side transverse and the maximum green sea pressure imposed on the deck transverse may be different, "carry-over" bending moment from the side transverse to the deck transverse is not applied for green sea load. The definition of effective bending span of vertical web frame on longitudinal bulkhead has been modified from the source criteria (ABS) in association with the definition of effective bending span in *Section 4/2.1.4 of the Rules* for the arrangement with a large bracket fitted on the back side of the web frame

2.6.4.d The requirements of shear area of deck transverses indicated in *Section 8/2.6.4.4* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/11.3 with slight modifications. c_1 factor has been adjusted based on the calibration with the sample ships. Also, additional shear area requirement for green sea pressure has been introduced.

2.6.4.e Deck transverses in one cross section are forming "transverse ring" of the hull structure. Therefore, the required section modulus and shear area for deck transverses in accordance with *Sections 8/2.6.4.3* and *2.6.4.4* of the *Rules* are to be constantly applied over the clear of end brackets, i.e. no reduction of the requirements is allowed towards the mid-span.

2.6.5 Side transverses

2.6.5.a The requirements of shear area of side transverses of *Section 8/2.6.5.1* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/11.7 with slight modifications. C_u and C_l factors indicated in *Table 8.2.13* of the *Rules* have been adjusted based on the calibration with the sample ships. Also, specific instructions have been added in the definition of effective length of upper bracket of the side transverse, h_u, and location to be taken for the design pressure, P_u, for the structure where deck transverses are fitted above deck and the inner hull longitudinal bulkhead is arranged with a large top wing structure.

2.6.5.b *Section 8/2.6.5.2* of the *Rules* specifies the distribution of the required shear area of side transverse. This distribution is similar to the distribution of required shear area applied in *Section 8/7* of the *Rules* except that where cross ties are fitted in wing cargo tanks the required shear area along the span is to be tapered linearly between the upper and lower parts. The same distribution of the required shear area is also applied for vertical web on longitudinal bulkhead.

2.6.6 Vertical web frames on longitudinal bulkhead

2.6.6.a The requirements of the web depth of vertical web frames on longitudinal bulkheads indicated in *Section 8/2.6.6.1* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/11.11.3.

2.6.6.b The requirements of section modulus of vertical web frames on longitudinal bulkheads indicated in *Section 8/2.6.6.2* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/15.3.1. C_u and C_l factors indicated in *Table 8.2.14* of the *Rules* have been adjusted based on the calibration with the sample ships. Also, the definition of effective bending span of vertical web frame on longitudinal bulkhead has been modified from the source criteria (ABS) in association with the definition of effective bending span in *Section 4/2.1.4* of the *Rules* for the arrangement with a large bracket fitted on the back side of the web frame.

2.6.6.c *Section 8/2.6.6.3* of the *Rules* specifies the distribution of the required section modulus of vertical web frame on longitudinal bulkhead. This distribution is similar to the distribution of required section modulus applied in *Section 8/7 of the Rules* except that the required section modulus at the mid-span is 70% of the required section modulus for the lower part. Similar distribution of the required section modulus is also applied for horizontal stringer on transverse bulkhead.

2.6.6.d The requirements of shear area of vertical web frames on longitudinal bulkheads are based on ABS Rules Pt.5 Ch.1 Sec.4/15.3.1 with slight modifications. C_u and C_l factors indicated in *Table 8.2.15* of the *Rules* have been adjusted based on the calibration with the sample ships.

2.6.6.e *Section 8/2.6.6.5* of the *Rules* specifies the distribution of the required shear area of vertical web frame on longitudinal bulkhead. This distribution is similar to the distribution of required shear area applied in *Section 8/7* of the *Rules* except that where cross ties are fitted in wing or centre cargo tank the required shear area along the span is to be tapered linearly between the upper and lower parts. The same distribution of the required shear area is also applied for side transverse.

2.6.7 Horizontal stringers on transverse bulkheads

2.6.7.a The requirements of the web depth of horizontal stringers on transverse bulkheads indicated in *Section 8/* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/11.11.4. The minimum effective bending span for the calculation of the required web depth has been adjusted based on the calibration with the sample ships

2.6.7.b The requirements of section modulus of horizontal stringers on transverse bulkheads indicated in *Section 8/2.6.7.2* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/15.5.1.

2.6.7.c *Section 8/2.6.7.3 of the Rules* specifies the distribution of the required section modulus of horizontal stringers on transverse bulkhead. This distribution is similar to the distribution of required section modulus applied in *Section 8/7* of the *Rules* except that the required section modulus at the mid-span is 70% of the required section modulus for the ends. Similar distribution of the required section modulus is also applied for vertical web frame on longitudinal bulkhead.

2.6.7.d The requirements of shear area of horizontal stringers on transverse bulkheads indicated in *Section 8/2.6.7.4* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/15.5.2 with slight modification of shear force.

2.6.7.e *Section 8/2.6.7.5* of the *Rules* specifies the distribution of the required shear area of horizontal stringers on transverse bulkhead. This distribution is the same as the distribution of required shear area applied in *Section 8/7 of the Rules*

2.6.8 Cross ties

2.6.8.a The requirements for cross ties indicated in *Section 8/2.6.8.1* of the *Rules* are based on ABS Rules Pt.5 Ch.1 Sec.4/15.11. The working compressive loads are to be obtained based on *Table 8.2.9* of the *Rules* with averaging the pressure at both ends of cross tie. The permissible compressive loads are to be obtained based on the criteria as given in *Section 10* of the *Rules*. The utilisation factors for cross tie have been adjusted based on the calibration with the sample ships.

2.6.8.b The requirements of the end connection of cross tie as indicated in *Section 8/2.6.8.2* of the *Rules* are primarily derived from ABS Rules Pt.5 Ch.1 Sec.4/15.11. DNV and LR Rules have similar requirements.

2.6.8.c The requirements of the end connection of cross tie as indicated in *Section 8/2.6.8.3* of the *Rules* are primarily derived from ABS Rules Pt.5 Ch.1 Sec.4/15.11. DNV and LR Rules have similar requirements.

2.6.9 Primary support members located beyond 0.4*L* amidships

2.6.9.a It is considered that for *2.6.9.1* of the *Rules*, no information in addition to that shown in the Rules is necessary to explain the background.

2.6.9.b The formula as given in *2.6.9.2* of the *Rules* is the "scaling" formula converting the required section modulus in the midship region to that in the region beyond 0.4*L* with taking account the differences of material yield strength and the working bending moment.

2.6.9.c The formula as given in *2.6.9.3* of the *Rules* is the "scaling" formula converting the required shear area in the midship region to that in the region beyond 0.4*L* with taking account the differences of material yield strength and the working shear force.