Impact of IACS Harmonized CSR on Tankers

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Agenda

- Introduction
- Increasing of Steel Weight For Tankers
- Some Technique Issues
- Conclusion

Introduction

MARIC, founded in 1950, is the largest and most comprehensive ship and offshore structure researching, developing, designing and engineering organization in China. MARIC is the research, development and design center of CSSC.

Steel Weight Impact

SAFTY

CSR-H
>=CSR

→

STEEL WEIGHT

CSR-H
>=CSR

Tankers For Assessment

Size / Principals	VLCC	Suezmax	Aframax	Panamax	MR
LBP (m)	320	264	234	220	176
B (m)	60	48	42	32.26	32.2
D (m)	30.5	24	21.6	21.2	18.6
Ts (m)	22.5	17.5	15.45	14.7	12.4
DWT (kilo ton)	320	163	115	76	48

Increase of Steel Weight

Increasing of steel weight within mid cargo region: about 1%~2%

Size / Criteria	VLCC	Suezmax	Aframax	Panamax	MR
Prescriptive requirement	182	50	74	11	15
FEA	38	45	31	41	26
Total	+220	+95	+105	+52	+41
Percentage	1.2%	0.8%	1.9%	1.0%	1.6%

Technique Issues

- Rule min. thickness
- Internal pressure for S+D condition
- Draught of two loading patterns for FEA
- Coarse mesh yield criteria
- Buckling problem in foremost cargo region
- Ultimate buckling capacity for stiffeners
- Estimation of design period

Rule Min. Thickness 1/5

location	area	HCSR	CSR-OT	CSR-BC
keel		$7.5+0.03L_2$	$6.5+0.03L_2$	7.5+0.03L
bottom	Fore part	$6.5+0.03L_2$	$4.5+0.03L_2$	5.5+0.03L
	Machinery space/ aft part	$7.0+0.03L_2$	$4.5+0.03L_2$	5.5+0.03L
	elsewhere	$5.5+0.03L_2$	$4.5+0.03L_2$	5.5+0.03L
Side shell/bilge	Fore part	$6.5+0.03L_2$	$4.5+0.03L_2$	$0.85L^{1/2}$
	Machinery space/ aft part	$7.0+0.03L_2$	$4.5+0.03L_2$	$0.85L^{1/2}$
	elsewhere	$5.5+0.03L_2$	$4.5+0.03L_2$	$0.85L^{1/2}$
Lower decks/flats	Machinery space	3.3+0.0067s	3.3+0.0067s	6.5
Inner bottom	Machinery space	$6.6+0.024L_2$	$6.5+0.02L_2$	6.6+0.024L
	elsewhere	$5.5+0.03L_2$	$4.5+0.02L_2$	5.5+0.03L

Rule Min. Thickness 2/5

location	area	HCSR	CSR-OT	CSR-BC
Internal tank boundary, trans./long. W.T. BHD(exclude inner side, hopper tank top, top wing tank long. BHD of BC)		$4.5+0.02L_2$	$4.5+0.02L_2$	$0.6L^{1/2}$
Non-tight BHD, wash BHD, BHD between dry spaces		$4.5+0.01L_2$	$4.5+0.01L_2$	6.5
Stiffeners and attached end brackets	W.T. boundary	$3.5+0.015L_2$	$3.5+0.015L_2$	$3.0+0.015L_2$
	elsewhere	$3.0+0.015L_2$	$2.5+0.015L_2$	$3.0+0.015L_2$
Double bottom centerline girder	Machinery space	$3.5+1.55L_2^{1/3}$	$5.5+0.025L_2$	$3.5+1.55L^{1/3}$
	elsewhere	$5.5+0.025L_2$	$5.5+0.025L_2$	$0.6L_2^{1/2}$
Other bottom girder	Machinery space	$1.0+1.7L_2^{1/3}$	$5.5+0.02L_2$	$1.0+1.7L^{1/3}$
	Fore part	$0.7L_2^{1/2}$	$5.5+0.02L_2$	$0.7L_2^{1/2}$
	elsewhere	$5.5+0.02L_2$	$5.5+0.02L_2$	$0.6L_2^{1/2}$

Rule Min. Thickness 3/5

location	area	HCSR	CSR-OT	CSR-BC
Girder bounding a duct keel		$2.5+0.8L_2^{1/2}$	$5.5+0.02L_2$	$2.5+0.8L^{1/2}$
Bottom floor	Machinery space	$1.0+1.7L_2^{1/3}$	$5.5+0.02L_2$	$1.0+1.7L^{1/3}$
	Fore part	$0.7L_2^{1/2}$	$5.5+0.02L_2$	$0.7L_2^{1/2}$
	elsewhere	$0.6L_2^{1/2}$	$5.0+0.015L_2$	$0.6L_2^{1/2}$
Aft peak floor		$0.7L_2^{1/2}$	$5.5+0.02L_2$	$0.7L_2^{1/2}$
Web plate of PSM in double hull	Fore part/aft part	$0.7L_2^{1/2}$	$6.5+0.015L_2$	$0.7L_2^{1/2}$
	Machinery space	$0.6L_2^{1/2}$	$5.5+0.015L_2$	$0.6L_2^{1/2}$
	elsewhere	$0.6L_2^{1/2}$	$5.0+0.015L_2$	$0.6L_2^{1/2}$
Web and flange of other PSM	Fore part/aft part	$0.7L_2^{1/2}$	$6.5+0.015L_2$	$0.7L_2^{1/2}$
	elsewhere	$0.6L_2^{1/2}$	$5.5+0.015L_2$	$0.6L_2^{1/2}$

Rule Min. Thickness 4/5

Elements	Scantling locations	Areas	Impact on Oil Tankers and brief explanation
Shell	Keel		**0.5~1.0mm ↑** for all OTs with longi. centerline BHD
	Bottom/Side shell/Bilge	Fore Part	Not critical
		Machinery space/ Aft part	**0.5~2.0mm ↑** except shell plating connected with stern frame
		Elsewhere	**0.5~1.0mm ↑** for regions outside fender contact zone
Inner bottom		Machinery space	Not critical
		Elsewhere	● **0.5mm ↑** for some Suezmax ● If IB plating with HT36, more increasing
D.B centerline girder		Machinery space	Not critical
Other bottom girder		Machinery space	Not critical
		Fore part	**0.5mm ↑** for local areas
Bottom floor		Machinery space	Not critical
		Fore part	**0.5mm ↑** for local areas
		Elsewhere	Not critical
Aft peak floor			**0.5mm ↑**
Web plates of other PSM in double hull		Machinery space	Not critical
		Elsewhere	**0.5~1.0mm ↑** for upper part of side trans. and platforms in DH
Web and flanges of other PSM		Aft part/Fore part	**0.5~1.0mm ↑**
		Elsewhere	Only for VLCC: ● **0.5mm ↑** for deck trans. and upper part of vert. trans. in C.O.T. ● **0.5mm ↑** for PSM in machinery space

Rule Min. Thickness 5/5

Possible modifications suggested by CANSI:

- **For the specified structural members for oil tankers or bulk carriers, e.g. PSM in cargo tanks or in double hull, the individual requirement is to be distinguished, equal to CSR-OT or CSR-BC respectively**
- **If the Rule Min. thickness requirement is the dominant criteria for the specified area, but only for any one of oil tankers or bulk carriers, e.g. keel plate and inner bottom plating for oil tankers, the min. requirement not the envelop requirement is preferable.**
- **New increase for shell plating thickness for machinery space and aft part is too conservative and is suggested to be taken as the envelop requirement of CSR-BC and CSR-OT.**

Internal Pressure for S+D Condition 1/11

CSR-OT (S+D)

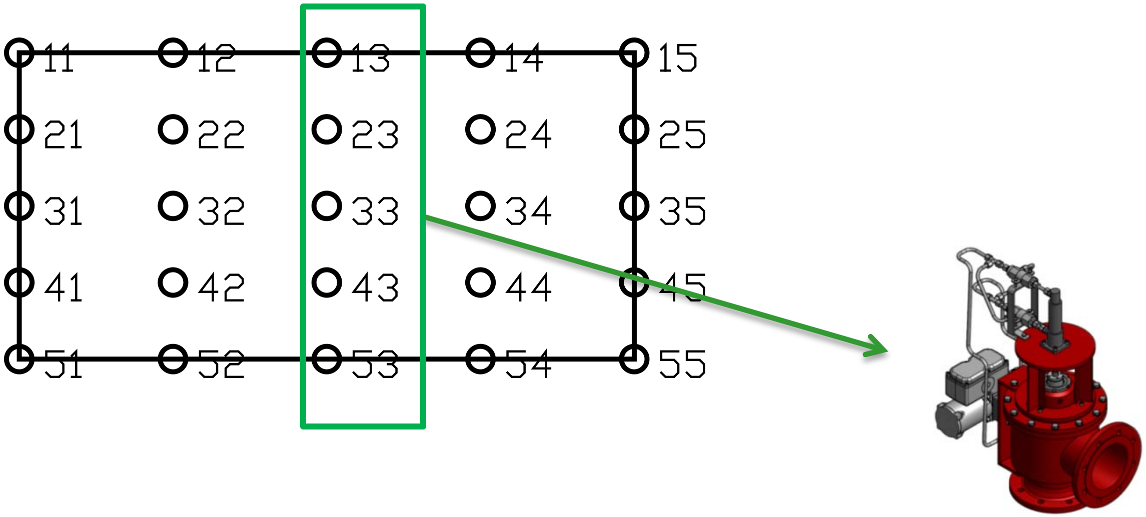
$$P_{in} = P_{in-tk} + P_{valve} - 25 + P_{in-dyn}$$

CSR-H (S+D)

$$P_{in} = P_{IS} + P_{ID} = P_{in-tk} + P_{valve} + P_{in-dyn}$$

There is no reduction in internal pressure formula for CSR-H.

Internal Pressure for S+D Condition 2/11



Possible positions where valve is located

If the vapor pressure near valve reach the setting pressure, valve will automatically open, and pressure decreases.

Internal Pressure for S+D Condition 3/11

Internal pressure for CSR-OT

Design load set (S+D)		3 (due to cargo pressure)				
Load cases	Point location	13	23	33	43	53
Head Sea	1	4.3	4.3	4.3	4.3	4.3
	2	8.6	8.6	8.6	8.6	8.6
	3	14.3	14.3	14.3	14.3	14.3
Oblique sea	4a	4.3	4.3	4.3	4.3	4.3
	4b	4.3	4.3	4.3	4.3	4.3
Beam sea	5a	44.3	33.5	22.7	11.9	1.1
	5b	1.1	11.9	22.7	33.5	44.3
	6a	27.3	21.9	16.5	11.1	5.7
	6b	5.7	11.1	16.5	21.9	27.3
	7a	32.8	26.3	19.8	13.3	6.9
	7b	6.9	13.3	19.8	26.3	32.8

Possible positions where valve is located

Internal Pressure for S+D Condition 4/11

Internal pressure for CSR-H

Design load set (S+D)	OT-1 (Full load condition)					OT-2 (Partial load condition)				
Point location / Load cases	13	23	33	43	53	13	23	33	43	53
HSM-1	25.0	29.8	34.6	39.4	44.2	25.0	29.6	34.2	38.8	43.4
HSM-2	44.2	39.4	34.6	29.8	25.0	43.4	38.8	34.2	29.6	25.0
HSA-1	25.0	31.1	37.1	43.2	49.2	25.0	29.8	34.6	39.5	44.3
HAS-2	49.2	43.2	37.1	31.1	25.0	44.3	39.5	34.6	29.8	25.0
FSM-1	28.3	27.5	26.7	25.8	25.0	31.3	29.7	28.2	26.6	25.0
FSM-2	25.0	25.8	26.7	27.5	28.3	25.0	26.6	28.2	29.7	31.3
BSR-1P	43.4	43.4	43.4	43.4	43.4	45.5	45.5	45.5	45.5	45.5
BSR-2P	43.4	43.4	43.4	43.4	43.4	45.5	45.5	45.5	45.5	45.5
BSR-1S	43.4	43.4	43.4	43.4	43.4	45.5	45.5	45.5	45.5	45.5
BSR-2S	43.4	43.4	43.4	43.4	43.4	45.5	45.5	45.5	45.5	45.5
BSP-1P	33.4	34.7	36.1	37.5	38.9	33.9	34.5	35.1	35.6	36.2
BSP-2P	38.9	37.5	36.1	34.7	33.4	36.2	35.6	35.1	34.5	33.9
BSP-1S	33.4	34.7	36.1	37.5	38.9	33.9	34.5	35.1	35.6	36.2
BSP-2S	38.9	37.5	36.1	34.7	33.4	36.2	35.6	35.1	34.5	33.9
OST-1P	35.3	33.3	31.3	29.3	27.3	36.1	33.4	30.8	28.1	25.5
OST-2P	27.3	29.3	31.3	33.3	35.3	25.5	28.1	30.8	33.4	36.1
OST-1S	35.3	33.3	31.3	29.3	27.3	36.1	33.4	30.8	28.1	25.5
OST-2S	27.3	29.3	31.3	33.3	35.3	25.5	28.1	30.8	33.4	36.1
OSA-1P	57.7	50.6	43.5	36.4	29.2	59.2	52.0	44.8	37.6	30.4
OSA-2P	29.2	36.4	43.5	50.6	57.7	30.4	37.6	44.8	52.0	59.2
OSA-1S	57.7	50.6	43.5	36.4	29.2	59.2	52.0	44.8	37.6	30.4
OSA-2S	29.2	36.4	43.5	50.6	57.7	30.4	37.6	44.8	52.0	59.2

Internal Pressure for S+D Condition 5/11

Scantling Changes Due To Local Pres. According to IACS CA

VLCC plate results

Ref.	Offered Net Thickness (mm)	Prescriptive								Increase Scantling impact			
		CSR			CSR-H			Difference in net CSRH-CSR [mm] Note 1		CSR-H			Difference in net max Final-Offered [mm]
		CSR Net. Req. [mm]	Criterion	CSR Buckling	CSRH Net. Req. (mm)	Criterion	CSR-H Buckling			Final Presc [mm] Note 2	Final FE [mm] Note 3	Criteria	
MD08	19.0*	11.0	Local, Min T	0.81	11.0	Local Min.T	0.78			19.0	19.0		
IB01	16.0	15.0	Local, Press	0.66	15.5	Local Press	0.58	0.5		16.0	16.0		
IB02	16.0	16.0	Local, Press	0.68	16.5	Local Press	0.60	0.5		16.5	16.0	Presc Local Press	0.5
IB03	16.0	16.0	Local, Press	0.68	16.5	Local Press	0.61	0.5		16.5	16.0	Presc Local Press	0.5
IB04	16.0	16.0	Local, Press	0.68	16.5	Local Press	0.61	0.5		16.5	16.0	Presc Local Press	0.5
IB05	16.0	16.0	Local, Press	0.68	16.5	Local Press	0.60	0.5		16.5	16.0	Presc Local Press	0.5
IB06	16.0	16.0	Local, Press	0.68	16.5	Local Press	0.60	0.5		16.5	16.0	Presc Local Press	0.5
HPR01	22.0	17.0	Local, Press	0.56	18.5	Local Press	0.52	1.5		22.0	22.0		
HPR02	16.5	16.0	Local, Press	0.59	16.5	Local Press	0.55	0.5		16.5	16.5		
HPR03	19.0	16.0	Local, Press	0.40	16.5	Local Press	0.50	0.5		19.0	19.0		
IH01	15.0	14.5	Local, Press	0.41	15.0	Local Press	0.44	0.5		15.0	15.0		
IH02	14.0	13.5	Local, Press	0.47	14.0	Local Press	0.45	0.5		14.0	14.0		
IH03	13.5	12.5	Local, Press	0.50	13.0	Local Press	0.55	0.5		13.5	13.5		
IH04	13.0	11.5	Local, Press	0.62	12.0	Local Press	0.65	0.5		13.0	13.0		
IH05	13.0	11.0	Local, Min T	0.91	11.0	Local Press	0.85			13.0	13.0		
IH06	14.0	11.0	Local, Min T	0.94	11.0	Local Min.T	0.93			14.0	14.0		

Internal Pressure for S+D Condition 6/11

Suezmax plate results

Ref	Offered Net thickness [mm]	Prescriptive							Increase Scantling Impact			
		CSR			CSR-H			Difference in net CSRH-CSR [mm] Note 1	CSR-H			Difference in net max Final-Offered [mm]
		CSR Net Req. [mm]	Criterion	CSR Buckling	CSR-H Net Req. [mm]	Criterion	CSR-H Buckling		Final Presc. [mm] Note 2	Final FE [mm] Note 3	Criteria	
IB1	13	13.0	Local, press	0.66	13.5	Local, press	0.64	0.5	13.5	13.0	Local, press	0.5
IB2	13	13.0	Local, press	0.66	13.5	Local, press	0.64	0.5	13.5	13.0	Local, press	0.5
IB3	13	13.0	Local, press	0.66	13.5	Local, press	0.64	0.5	13.5	13.0	Local, press	0.5
IB4	13	13.0	Local, press	0.66	13.5	Local, press	0.65	0.5	13.5	13.0	Local, press	0.5
IB5	13	13.0	Local, press	0.66	13.5	Local, press	0.65	0.5	13.5	13.0	Local, press	0.5
IB6	16.5	13.0	Local, press	0.55	13.5	Local, press	0.55	0.5	16.5	16.5	Local, press	0.0
HPR1	16	13.0	Local, press	0.54	13.0	Local, press	0.58	0.0	16.0	16.0	Local, press	0.0
HPR2	15	12.5	Local, press	0.44	12.5	Local, press	0.54	0.0	15.0	15.0	Local, press	0.0
MD1	19	9.5	Local, Min T	0.72	9.5	Local, Min T	0.72	0.0	19.0	19.0	Local, Min T	0.0
MD2	18.5	9.5	Local, Min T	0.73	9.5	Local, Min T	0.73	0.0	18.5	18.5	Local, Min T	0.0
MD3	18.5	9.5	Local, Min T	0.72	9.5	Local, Min T	0.72	0.0	18.5	18.5	Local, Min T	0.0
MD4	18.5	9.5	Local, Min T	0.71	9.5	Local, Min T	0.71	0.0	18.5	18.5	Local, Min T	0.0
MD5	18.5	9.5	Local, Min T	0.71	9.5	Local, Min T	0.72	0.0	18.5	18.5	Local, Min T	0.0
MD8	18.5	10.5	Local, Min T	0.73	10.5	Local, Min T	0.74	0.0	18.5	18.5	Local, Min T	0.0
IH1	14	12.0	Local, press	0.24	12.0	Local, press	0.42	0.0	14.0	14.0	Local, press	0.0
IH2	12.5	12.5	Local, press	0.32	13.0	Local, press	0.59	0.5	13.0	12.5	Local, press	0.5
IH3	11.5	11.0	Local, press	0.64	12.0	Local, press	0.77	1.0	12.0	11.5	Local, press	0.5
IH4	12	11.0	Local, press	0.96	12.0	Local, press	1.02	1.0	12.5	12	Local, buckling	0.5
IH5	13.5	11.0	Local, Min T	0.97	11.0	Local, Min T	0.93	0.0	13.5	13.5	Local, Min T	0.0
ST3	13.5	9.0	Local, Min T	0.28	9.5	Local, Min T	0.41	0.5	13.5	13.5	Local, Min T	0.0
ST2	12	9.0	Local, Min T	0.18	9.5	Local, Min T	0.36	0.5	12.0	12.0	Local, Min T	0.0
ST1	11.5	9.0	Local, Min T	0.70	9.5	Local, Min T	0.72	0.5	11.5	11.5	Local, Min T	0.0

Internal Pressure for S+D Condition 7/11

Suezmax stiffener results

Ref.	Net Offered SM CSR [cm3]	Prescriptive							Increase Scantling impact			
		CSR Net Req. SM [cm3]			CSR-H Net. Req. SM [cm3]			[CSR-H - CSR] / CSR [%]	CSR-H			Difference in net max Final [CSRH-offered] /Offered [%]
		CSR Net Req. SM [cm3]	Criterion	CSR Buckling	CSR-H Net. Req. SM [cm3]	Criterion	CSR-H buckling		Final Presc [cm3] Note 2	Final FE [cm3] Note 3	Criteria	
IB1	1595	1485	local, press	0.65	1702	local, press	0.81	14.6%	1702	1595	local, press	6.7%
IB2	1595	1485	local, press	0.65	1702	local, press	0.82	14.6%	1702	1595	local, press	6.7%
IB3	1595	1485	local, press	0.65	1702	local, press	0.82	14.6%	1702	1595	local, press	6.7%
IB4	1595	1485	local, press	0.65	1702	local, press	0.83	14.6%	1702	1595	local, press	6.7%
IB5	1595	1485	local, press	0.65	1702	local, press	0.83	14.6%	1702	1595	local, press	6.7%
IB6	1625	1485	local, press	0.64	1702	local, press	0.75	14.6%	1702	1625	local, press	4.7%
HPR1	1845	1886	local, press	0.64	2191	local, press	0.74	16.2%	2191	1845	local, press	18.7%
HPR2	1566	1602	local, press	0.46	1809	local, press	0.60	12.9%	1809	1566	local, press	15.5%
MD1	1063	691	local, press	0.87	698	local, press	0.91	1.0%	1063	1063	local, press	0.0%
MD2	1061	687	local, press	0.87	702	local, press	0.90	2.1%	1061	1061	local, press	0.0%
IH1	1196	1225	local, press	0.16	1339	local, press	0.25	9.3%	1339	1196	local, press	11.9%
IH2	990	997	local, press	0.16	1126	local, press	0.41	12.9%	1126	990	local, press	13.7%
IH3	821	844	local, press	0.29	1002	local, press	0.60	18.7%	1002	821	local, press	22.0%
IH4	844	768	local, press	0.50	1003	local, press	0.83	30.6%	1003	844	local, press	18.8%
IH5	772	648	local, press	0.61	938	local, press	0.94	44.7%	938	772	local, press	21.4%
ST3	378	86	local, press	0.23	N.A.	N.A.	0.46	N.A.	378	378	N.A.	0.0%
ST2	265	115	local, press	N.A.	N.A.	N.A.	N.A.	N.A.	265	265	N.A.	0.0%
ST1	374	148	local, press	0.57	N.A.	N.A.	0.74	N.A.	374	374	N.A.	0.0%
CL1	1794	1761	local, press	0.53	1884	local, press	0.58	7.0%	1884	1794	local, press	5.0%
CL2	1139	1145	local, press	0.17	1210	local, press	0.27	5.8%	1210	1139	local, press	6.3%
CL3	1018	1000	local, press	0.15	1062	local, press	0.30	6.2%	1062	1018	local, press	4.3%
CL4	943	963	local, press	0.23	1030	local, press	0.35	7.0%	1030	943	local, press	9.2%
CL5	1014	817	local, press	0.28	922	local, press	0.41	12.9%	1014	1014	local, press	0.0%
CL6	937	720	local, press	0.50	962	local, press	0.68	33.5%	962	937	local, press	2.7%
CL7	3484	563	local, press	0.82	907	local, press	0.69	61.0%	3484	3484	local, press	0.0%

Internal Pressure for S+D Condition 8/11

Aframax plate results

Ref.	Offered Net thickness [mm]	Prescriptive							Increase Scantling impact			
		CSR			CSR-H			Difference in net CSRH-CSR [mm] Note 1	CSR-H			Diff in net max Final-Offered [mm]
		CSR Net Req. [mm]	Criterion	CSR Buckling	CSR-H Net. Req. [mm]	Criterion	CSR-H Buckling		Final Presc [mm] Note 2	Final FE [mm] Note 3	Criteria	
IB1	16.0	16.0	Local	0.59	16.5	Local	0.59	0.5	16.5	16.0	Local	0.5
IB2	16.0	16.0	Local	0.59	16.5	Local	0.58	0.5	16.5	16.0	Local	0.5
IB3	16.0	16.0	Local	0.59	16.5	Local	0.59	0.5	16.5	16.0	Local	0.5
IB4	16.0	16.0	Local	0.59	17.0	Local	0.59	1.0	17.0	16.0	Local	1.0
IB5	16.0	16.0	Local	0.59	17.0	Local	0.62	1.0	17.0	16.0	Local	1.0
HPR1	16.0	16.0	Local	0.49	16.5	Local	0.61	0.5	16.5	16.0	Local	0.5
HPR2	15.5	15.5	Local	0.51	16.0	Local	0.59	0.5	16.0	15.5	Local	0.5
IH1	13.0	13.5	Local	0.46	13.5	Local	0.47	0	13.5	13.5	FE Buck	0.5
IH2	13.5	13.5	Local	0.53	14.0	Local	0.59	0.5	14.0	13.5	Local	0.5
IH3	12.0	12.0	Local	0.57	13.0	Local	0.68	1.0	13.0	12.0	Local	1.0
IH4	11.5	11.0	Local	0.96	11.5	Local	0.90	0.5	11.5	12.0	FE Buck	0.5
IH5	13.0	10.0	Minimum	0.95	10.5	Minimum	0.88	0.5	13.0	13.0		
BG1	13.5	13.5	Local	0.7	13.0	Local	0.66	-0.5	13.5	13.5		
BG2	14.0	10.0	Minimum	0.8	10.0	Minimum	0.85	0	14.0	14.0		
ST1	9.0	8.5	Minimum	0.5	9.0	Minimum	0.64	0.5	9.0	9.0	Minimum	
ST2	9.0	8.5	Minimum	0.1	9.0	Minimum	0.57	0.5	9.0	9.0	Minimum	
ST3	12.0	9.0	Minimum	0.5	9.0	Minimum	0.44	0	12.0	12.5	FE Buck	0,5
LL1	13.5	13.5	Local	0.6	14.0	Local	0.62	0.5	14.0	14.5	FE Buck	1,0

Internal Pressure for S+D Condition 9/11

Aframax stiffener results

Ref.	Net Offered SM [cm3]	Prescriptive							Increase Scantling impact			
		CSR			CSR-H				CSR-H			
		CSR Net Req. SM [cm3]	Criterion	CSR Buckling	CSRH Net. Req. SM [cm3]	Criterion	CSR-H Buckling	[CSRH - CSR] / CSR[%] Note 1	Final Presc [cm3] Note 2	Final FE [cm3] Note 3	Criteria	Difference in net max Final [CSRH-Offered] / Offered [%]
IB1	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB2	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB3	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB4	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB5	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB6	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB7	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB8	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB9	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB10	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB11	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB12	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB13	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB14	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB15	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
IB16	1561	1522	Local	0.61	1598	Local	0.7	5.0	1598	1598	Local	2.4
HPR23	1551	1529	Local	0.50	1572	Local	0.6	2.8	1572	1572	Local	1.4
HPR24	1445	1450	Local	0.45	1527	Local	0.6	5.3	1527	1527	Local	5.7
HPR25	1442	1377	Local	0.41	1483	Local	0.6	7.7	1483	1483	Local	2.9
HPR26	1442	1300	Local	0.37	1432	Local	0.5	10.1	1442	1442		
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
IH34	764	783	Local	0.15	895	Local	0.4	14.3	895	895	Local	17.2
IH35	764	738	Local	0.18	849	Local	0.4	15.0	849	849	Local	11.1
IH36	757	693	Local	0.24	808	Local	0.5	16.6	808	808	Local	6.8
IH38	757	663	Local	0.36	798	Local	0.6	20.4	798	798	Local	5.4
IH39	589	583	Local	0.40	708	Local	0.7	21.5	708	708	Local	20.2
IH40	589	548	Local	0.46	672	Local	0.7	22.7	672	672	Local	14.1
IH41	523	516	Local	0.53	636	Local	0.8	23.2	636	636	Local	21.4
IH42	523	481	Local	0.59	617	Local	0.9	28.3	617	617	Local	17.9
IH43	2793	443	Local	0.87	595	Local	0.7	34.3	2793	2793		
IH44	1959	448	Local	0.86	615	Local	0.8	37.4	1959	1959		
IH45	550	384	Local	0.74	581	Local	1.0	51.3	581	919	FE Buck	67.0

Internal Pressure for S+D Condition 10/11

Aframax stiffener results

Ref.	Net Offered SM [cm3]	Prescriptive							Increase Scantling impact			
		CSR			CSR-H				CSR-H			
		CSR Net Req. SM [cm3]	Criterion	CSR Buckling	CSRH Net. Req. SM [cm3]	Criterion	CSR-H Buckling	[CSRH - CSR] / CSR[%] Note 1	Final Presc [cm3] Note 2	Final FE [cm3] Note 3	Criteria	Difference in net max Final [CSRH-Offered] / Offered [%]
BG1	533	441	Local	0.55	428	Local	0.8	-3.0	533	533		
BG2	427	120	Local	0.49	399	Local	0.8	232.3	427	427		
LL25	1355	1449	Local	0.43	1580	Local	0.7	9.0	1580	1580	Local	16.6
LL26	1355	1308	Local	0.37	1420	Local	0.6	8.5	1420	1420	Local	4.8
LL27	1355	1201	Local	0.30	1292	Local	0.5	7.6	1355	1355		
LL28	1366	1108	Local	0.24	1199	Local	0.4	8.2	1366	1366		
LL29	1366	1057	Local	0.18	1134	Local	0.3	7.3	1366	1366		
LL30	6691	1349	Local	0.16	1450	Local	0.2	7.5	6691	6691		
LL31	956	956	Local	0.06	1030	Local	0.3	7.7	1030	1030	Local	7.8
LL32	953	905	Local	0.01	978	Local	0.2	8.1	978	978	Local	2.6
LL33	829	855	Local	0.06	926	Local	0.3	8.3	926	926	Local	11.7
LL34	829	804	Local	0.12	875	Local	0.4	8.8	875	875	Local	5.5
LL35	829	754	Local	0.18	830	Local	0.4	10.1	830	830	Local	0.1
LL36	827	708	Local	0.23	787	Local	0.5	11.2	827	827		
LL37	4905	991	Local	0.42	1107	Local	0.4	11.7	4905	4905		
LL38	644	660	Local	0.33	727	Local	0.7	10.2	727	727	Local	12.9
LL39	644	633	Local	0.39	714	Local	0.7	12.9	714	714	Local	10.9
LL40	644	603	Local	0.44	700	Local	0.8	16.0	700	700	Local	8.6
LL41	644	570	Local	0.50	683	Local	0.8	19.8	683	683	Local	6.0
LL42	578	534	Local	0.57	663	Local	0.9	24.1	663	665	FE Buck	15.0
LL43	578	493	Local	0.62	639	Local	1.0	29.6	639	639	Local	10.6
LL44	2827	461	Local	0.93	633	Local	0.8	37.4	2827	2827		
LL45	2261	443	Local	0.90	641	Local	0.8	44.6	2261	2261		
LL46	578	455	Local	0.79	620	Local	1.1	95.6	904	890	Pre Buck	56,4

Internal Pressure for S+D Condition 11/11

•For CSR-OT, Some members are dominated by S condition (load set 4)

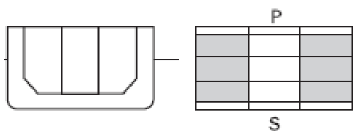
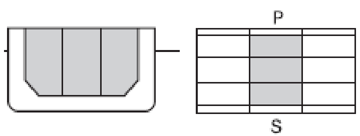
•For CSR-H, members of boundary of COT are all determined by S+D condition

•We suggest make some modification for the formula of internal pressure (S+D)

Ref.	CSR			HCSR		
	criterion	dom. Case	load	criterion	dom. Case	load
IB1	local,press	5, 6a	396.8	local,press	OT-1,HSM_1	363.903
IB2	local,press	5, 6a	393.3	local,press	OT-1,HSM_1	363.903
IB3	local,press	5, 6a	384.54	local,press	OT-1,BSP_1P	397.302
IB4	local,press	3, 2	388.21	local,press	OT-1,BSP_1P	400.425
IB5	local,press	3, 2	343.56	local,press	OT-1,HSM_1	363.93
IB6	local,press	3, 2	343.56	local,press	OT-1,HSM_1	363.93
IB7	local,press	3, 7b	382.9	local,press	OT-1,BSP_1P	397.023
HPR1	local,press	3, 2	343.56	local,press	OT-1,HSM_1	363.93
HPR2	local,press	3, 2	320.54	local,press	OT-1,HSM_1	341.387
IH1	local,press	3, 7b	314.47	local,press	OT-2,BSR_1P	328.536
IH2	local,press	3, 7b	303.69	local,press	OT-2,BSR_1P	318.319
IH3	local,press	3, 7b	249.79	local,press	OT-2,BSR_1P	267.232
IH4	local,press	3, 7b	206.67	local,press	OT-2,BSR_1P	226.364
IH5	local,press	4	135.81	local,press	OT-1,OSA_2S	169.759
IH6	local,press	4	118.71	local,press	OT-1,OSA_2S	152.898
IH7	local,min T	/	/	local,min T	/	/
IH8	local,min T	/	/	local,min T	/	/
ILL1	local,press	3, 7b	388.21	local,press	OT-1,BSP_1P	400.425
ILL2	local,press	3, 7b	378.26	local,press	OT-1,BSP_1P	370.647
ILL3	local,press	3, 7b	347.81	local,press	OT-1,BSP_1P	360.101
ILL4	local,press	3, 7b	316.11	local,press	OT-1,BSP_1P	328.461
ILL5	local,press	3, 7b	284.4	local,press	OT-1,BSP_1P	298.822
ILL6	local,press	3, 7b	242.14	local,press	OT-1,BSP_1P	254.636
ILL7	local,press	3, 7b	210.44	local,press	OT-2,BSR_1P	224.713
ILL8	local,press	3, 7b	168.17	local,press	OT-2,BSR_1P	186.995
ILL9	local,press	3, 7b	136.47	local,press	OT-2,BSR_1P	158.706
ILL10	local,min T	3, 5b	118.96	local,min T	/	/
ILL11	local,min T	3, 5b	85.12	local,min T	/	/

Two loading patterns for FEA 1/3

Difference between draughts for CSR-H and CSR-OT

No.	Loading Pattern	Draught		Notes
		CSR-H	CSR-OT	
A3		$0.65T_{SC}$	$0.55\ T_{SC}$	If conditions in the ship loading manual specify lesser draughts for loading pattern A3 or A13, then the max. specified draught in the ship's loading manual for the loading pattern is to be used.
A13		$0.7T_{SC}$	$0.65T_{SC}$	
A5		$0.65T_{SC}$	$0.8\ T_{SC}$	If conditions in the ship loading manual specify lesser draughts for loading pattern A5 or A11, then the min. specified draught in the ship's loading manual for the loading pattern is to be used.
A11		$0.6T_{SC}$	$0.7\ T_{SC}$	

Draught changes tend to make results more conservative

Two loading patterns for FEA 2/3

Segregation with three groups

SLOP T.	No.5 COT	No.4 COT	No.3 COT	No.2 COT	No.1 COT	
1	2	1	3	2	1	P
3		2	1	3	3	C
1	2	1	3	2	1	S

All tanks abreast empty or full will never appear

Segregation with two groups

SLOP T.	No.5 COT	No.4 COT	No.3 COT	No.2 COT	No.1 COT	
1	1	1	3	1	1	P
3		1	1	3	3	C
1	1	1	3	1	1	S

SLOP T.	No.5 COT	No.4 COT	No.3 COT	No.2 COT	No.1 COT	
1	2	1	1	2	1	P
1		2	1	1	1	C
1	2	1	1	2	1	S

All tanks abreast empty or full is possible, but neighbor tanks partially loaded

For normal loading pattern,
A3, A5, A11, A13 load pattern will never appear

Two loading patterns for FEA 3/3

An unreasonable segregation

SLOP T.	No.5 COT	No.4 COT	No.3 COT	No.2 COT	No.1 COT	
1	2	1	3	2	1	P
3		2	3	1	3	C
1	2	1	3	2	1	S

In this condition, load pattern like A3, A5, A11, A13 is possible, though this kind of segregation is seldom in practice

In case this condition appears, draughts according to loading manual for A3, A5, A11, A13 is as follows

No.	VLCC1	VLCC2	VLCC3	VLCC4	Average
A3	0.68Tsc	0.72Tsc	0.67Tsc	0.65Tsc	0.68Tsc
A5	0.83Tsc	0.71Tsc	0.74Tsc	0.73Tsc	0.75Tsc
A11	0.81Tsc	0.70Tsc	0.74Tsc	0.73Tsc	0.75Tsc
A13	0.67Tsc	0.68Tsc	0.67Tsc	0.65Tsc	0.67Tsc

Close to CSR-H

Close to CSR-OT

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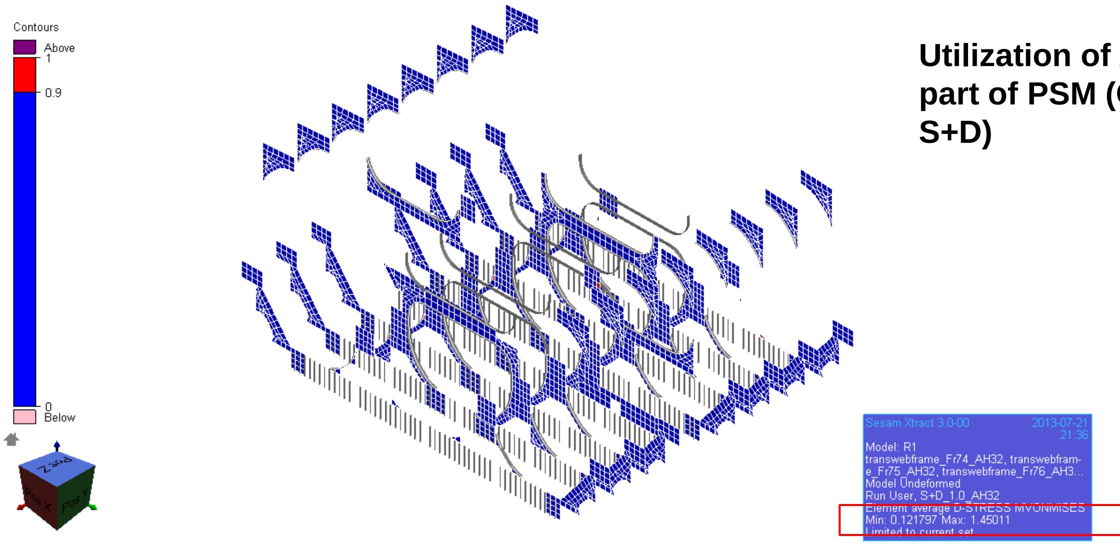
Coarse Mesh Yield Criteria 1/2

For plating of N.W.T. structural members, criteria for HT32 and HT36 steel increased

	CSR-OT		CSR-H		CSR-H / CSR-OT	
λ for N.W.T. members	1.0 (S+D)	0.8 (S)	1.0 (S+D)	0.8 (S)	S+D	S
MS	235.0	188.0	235.0	188.0	1.00	1.00
HT32	315.0	252.0	301.3	241.0	0.96	0.96
HT36	355.0	284.0	326.4	261.1	0.92	0.92

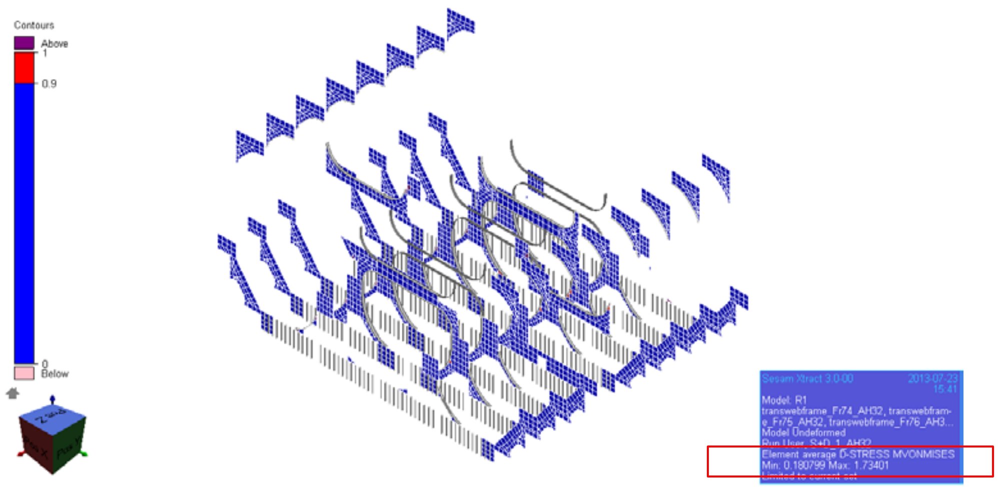
Coarse Mesh Yield Criteria 2/2



Utilization of AH32 part of PSM (CSR S+D)

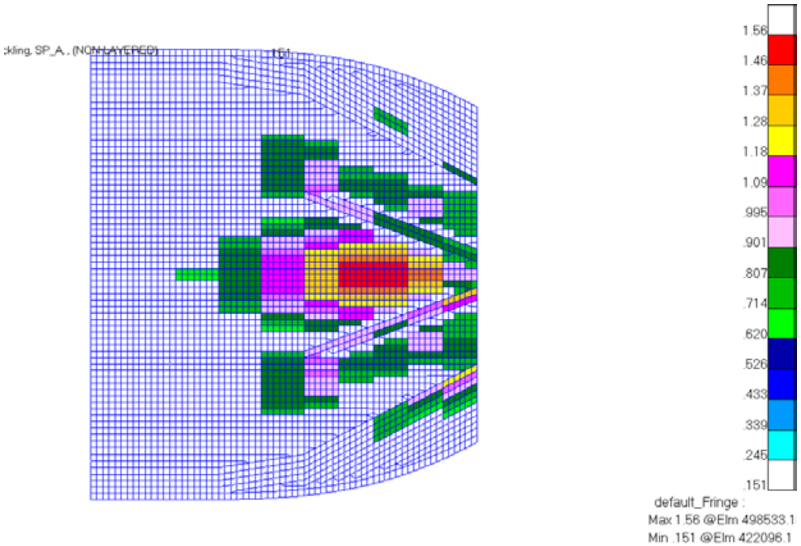
Considering internal loads increased compared to CSR-OT, the two factors together will induce steel weight increase for N.W.T. members

Utilization of AH32 part of PSM (CSR-H S+D)

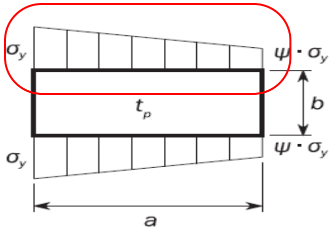


FEA for Foremost Cargo Region 1/2

Buckling problem for upper deck



Critical Load case	Panel in midship cargo tank	Panel in foremost cargo tank	
A1-HSM1		original	modified
σ_x (MPa)	205.0	68.3	60.4
σ_y (MPa)	13.2	85.0	78.2
τ (MPa)	14.5	1.4	1.6
t_{net} (mm)	14.5	12	14.5
Material	HT32	HT32	HT32
Buckling factor	0.811	1.331	0.949
Allowable factor	1.0	1.0	1.0
Buckling Ratio	0.811	1.331	0.949



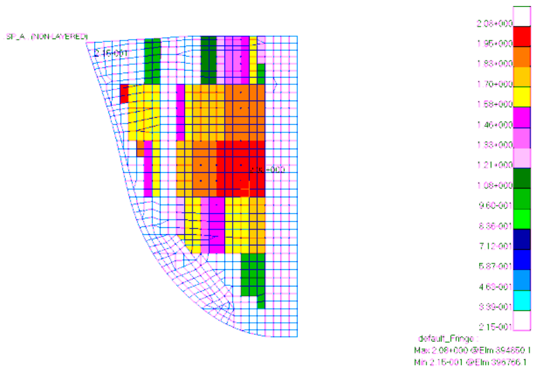
This may caused by:

•Large lateral pressure induced compressive stress on long edge of buckling panel

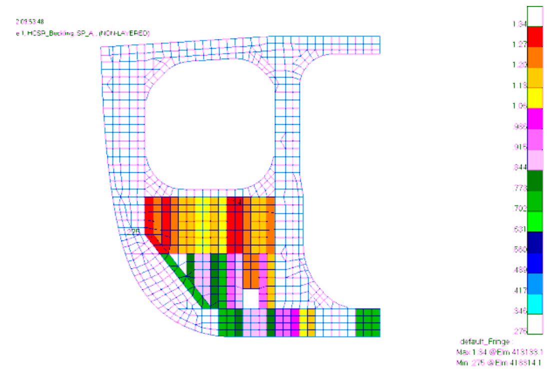
•Boundary of FE model is too near to the analysis area considered

FEA for Foremost Cargo Region 2/2

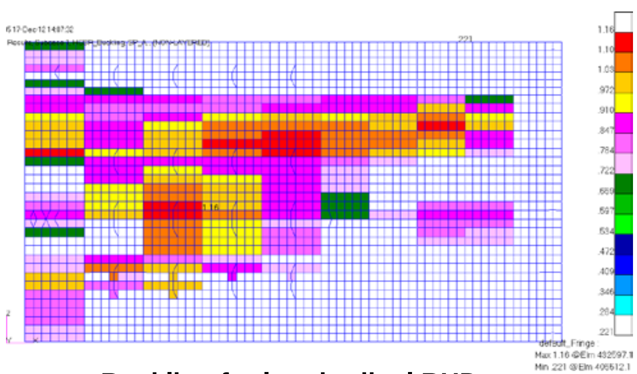
Similar phenomena of buckling problem was found for some other parts of structure



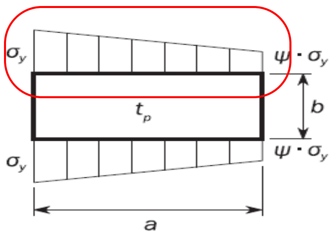
Buckling for collision BHD



Buckling for swash BHD



Buckling for longitudinal BHD



Ultimate Buckling Capacity for Stiffeners 1/2

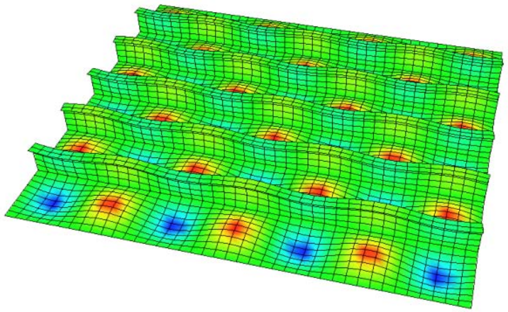
CSR-OT

3.3.2.2 The buckling utilisation factor for column buckling of stiffeners is to be taken as:

$$\eta = \frac{\sigma_x + \sigma_b}{\sigma_{yd}}$$

Where:

σ_x compressive axial stress in the stiffener, in N/mm², in way of the midspan of the stiffener. See *Section 3/5.2.3.1*



CSR-H

2.3.4 Ultimate buckling capacity

When $\sigma_a + \sigma_b + \sigma_w > 0$, the ultimate buckling capacity for stiffeners is to be checked according to the following interaction formula:

$$\frac{\gamma_c\ \sigma_a + \sigma_b + \sigma_w}{R_{eH}} S = 1$$

where:

σ_a : Effective axial stress, in N/mm², at mid span of the stiffener, acting on the stiffener with its attached plating.

$$\sigma_a = \sigma_x \frac{s\ t_p + A_s}{b_{eff1}\ t_p + A_s}$$

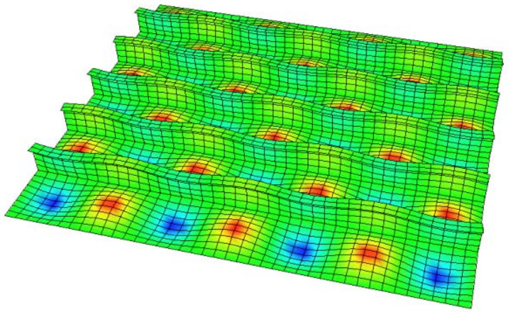
σ_x : Nominal axial stress, in N/mm², acting on the stiffener with its attached plating.

- For FE analysis, σ_x is the FE corrected stress as defined in [2.3.6] in the attached plating in the direction of the stiffener axis.
- For prescriptive assessment, σ_x is the axial stress calculated according to Ch 8, Sec 3, [2.2.1] at load calculation point of the stiffener, as defined in Ch 3, Sec 7, [3].

Ultimate buckling capacity for stiffeners 2/2

$$\sigma_a = \sigma_x \frac{st_p + A_s}{b_{eff1}t_p + A_s}$$

$$F = \frac{st_p + A_s}{b_{eff1}t_p + A_s}$$

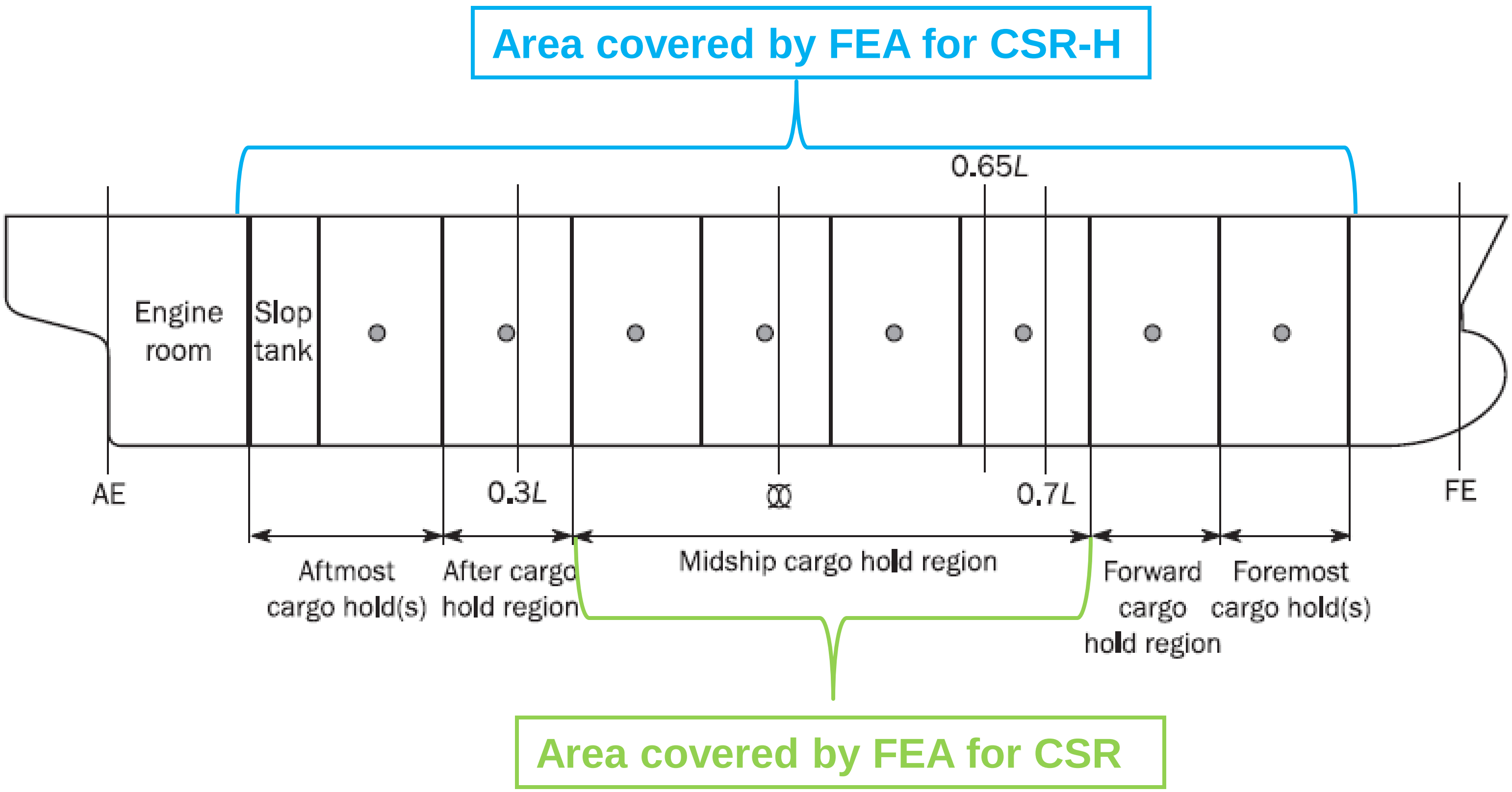


Vessel/Location		s (mm)	t_p (mm)	A_s (mm^2)	b_{eff1} (mm)	F (Factor)	CSR-H η_{act}	CSR-OT η_{column}	CSR-OT $\eta_{torsion}$
VLCC	DL	876.8	14.5	6508	669.0	1.186	1.02	0.73	0.89
	IHL	800	13.0	5120	605.6	1.195	1.07	0.73	0.89
Aframax	DL	820.8	14.0	6088	641.9	1.166	0.91	0.72	0.87
	IHL	790	11.0	2860	548.3	1.299	1.12	0.68	0.88
	LL	750	11.0	3042	528.8	1.275	1.04	0.67	0.86
Panamax	DL	786	11.5	2890	552.6	1.290	1.08	0.74	0.84
	IHL	670	9.0	2453	452.3	1.300	0.96	0.62	0.75
	LL	640	9.5	2098	459.5	1.265	1.11	0.71	0.82
MR	DL	800	10.0	2944	559.2	1.283	1.05	0.71	0.80
	IHL	648.8	9.5	2223	512.6	1.182	0.96	0.65	0.74
	LL	781.3	9.5	2613	549.3	1.282	1.06	0.68	0.74

The scale factor F for σx has obvious effect on stiffener buckling results for CSR-H

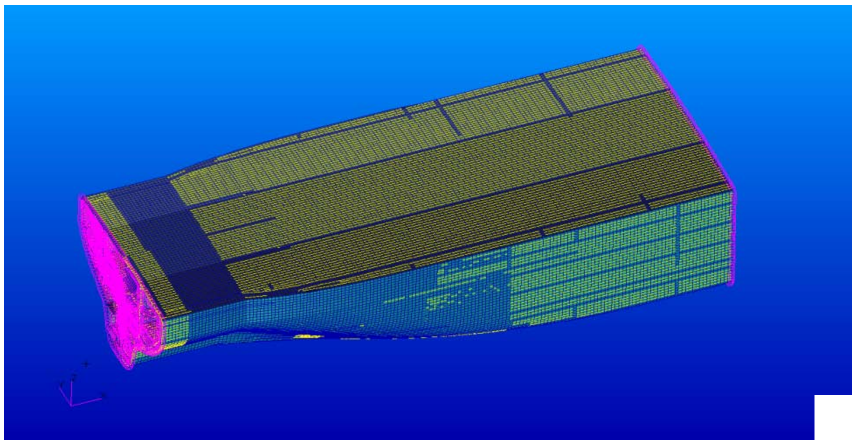
Estimation of Design Period

The main design period increase comes from FE analysis

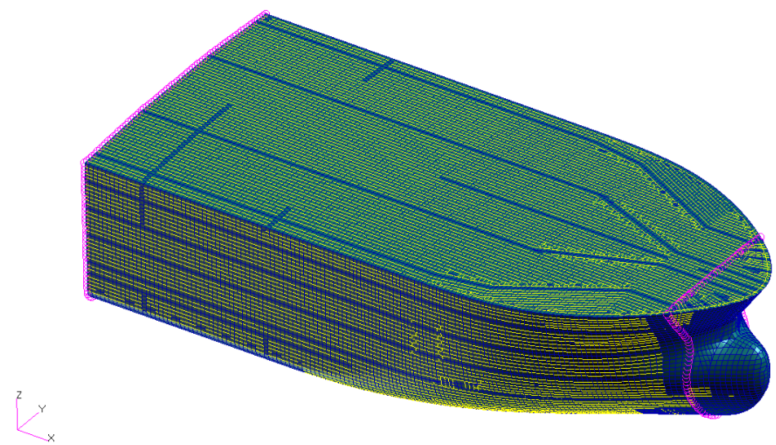


Estimation of Design Period

For coarse mesh analysis:



FE model for the aftmost cargo holds
(1.5 times more than CSR midship cargo)



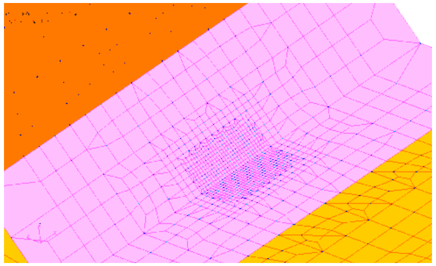
FE model for the foremost cargo holds
(1.5 times more than CSR midship cargo)

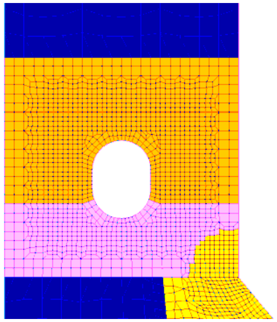
Estimation of Design Period

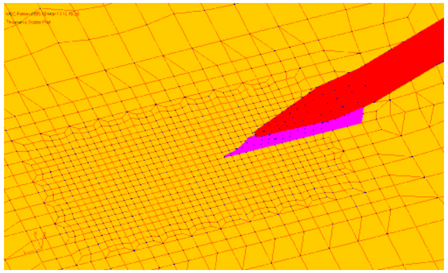
For fine mesh analysis:

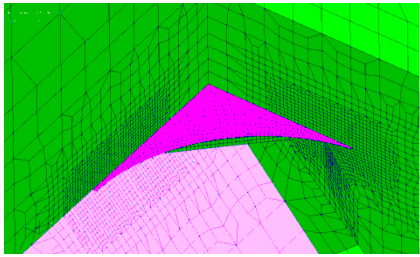
•Screening covers **the whole cargo hold region**

•If fine mesh needed for areas outside midship cargo hold region, much more work and time will be cost







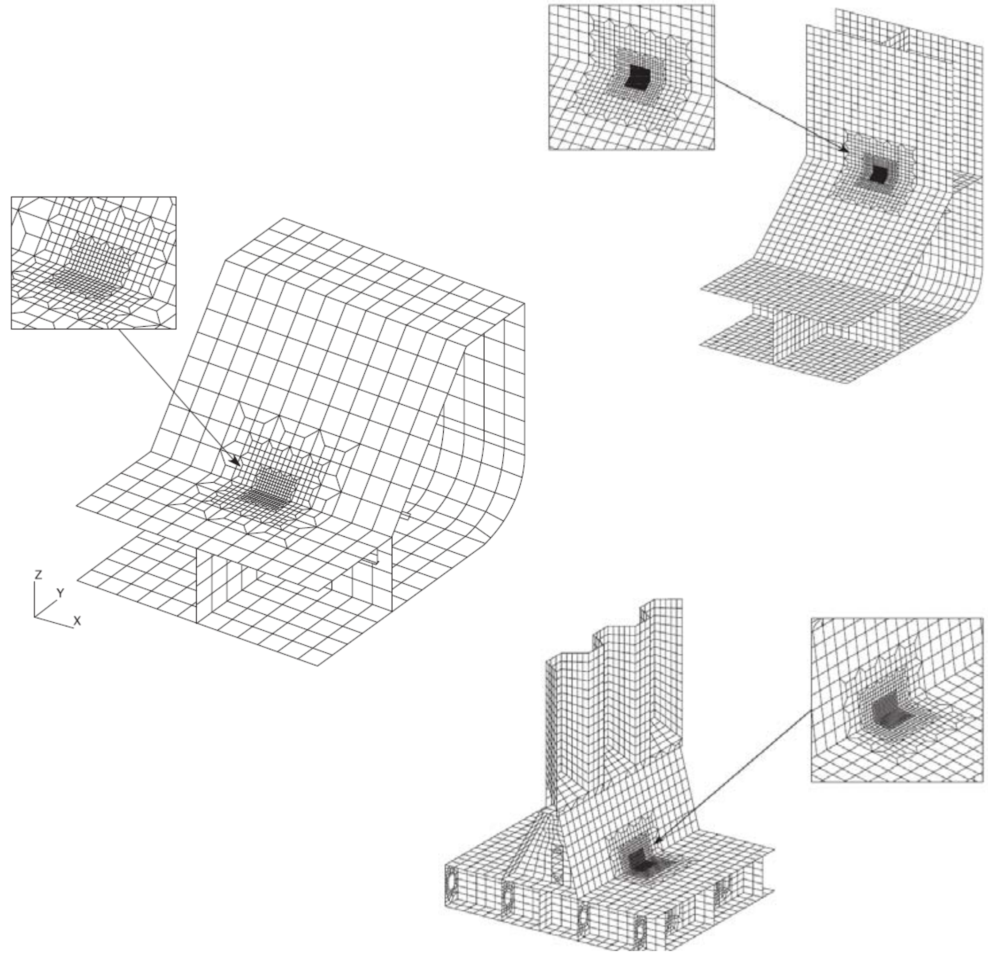


Estimation of Design Period

For fatigue analysis:

•**Additional area required for very fine mesh analysis**

•**Some fine mesh models have been analyzed according to yielding requirement are to be assessed by fatigue screening**



Conclusion

According to our consequence assessment, impact of CSR-H on tanker are as follows:

•The increase by prescriptive requirement is normally more than that by FE analysis for VLCC, Suezmax and Aframax with plane bulkhead. For Panamax and MR, the increase for corrugated bulkhead due to FE buckling is prominent

•The total increase of steel weight in midship cargo area is about 1%~2%

•The design, verification and approval period will be 3~5 times more than that for CSR

•Some technique issues are to be discussed further

Thanks for your attention!