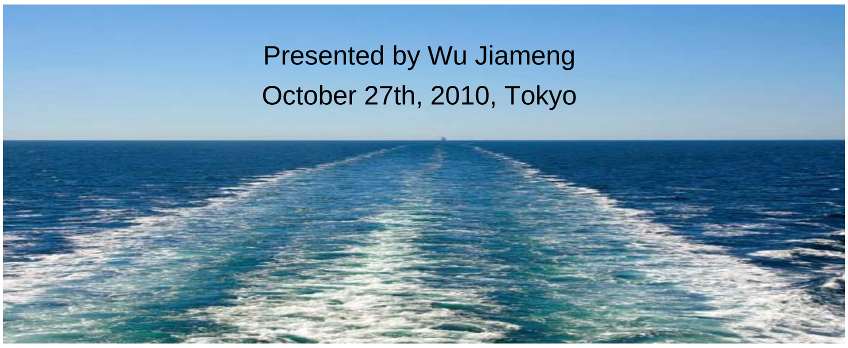
TSCF 2010 Shipbuilders Meeting Presentation

# Design Experience on CSR VLCC




中 国 船 舶 及 海 洋 工 程 设 计 研 究 院
MARINE DESIGN & RESEARCH INSTITUTE OF CHINA (MARIC)

1

## Agenda

- Introduction
- CSR impact on a 308,000DWT VLCC
- Design experience on CSR VLCC
- Conclusion

中 国 船 舶 及 海 洋 工 程 设 计 研 究 院
MARINE DESIGN & RESEARCH INSTITUTE OF CHINA (MARIC)

2

## Introduction of MARIC

**MARIC, founded in 1950, is the largest and most comprehensive ship and offshore structure researching, developing, designing and engineering organization in China. Now MARIC is the Research, Development and Design Center of CSSC.**

**MARIC is also:**
**-- Chairman of Design Committee of Chinese SNAME**
**-- Unit member of ITTC**
**-- Unit member of ISSC**



## Design Concept of MARIC

**Economy**

**Safety**

**Environmental**

***"ESE"* design concept is consistent with the *Green* and *low carbon.***

## Key features of CSR

- Net thickness approach
- New load model for strength calculation based on North Atlantic environments
- Increased design fatigue standard of 25 years North Atlantic
- Coating performance standard
- Enhanced strength assessments:
  - Hull girder ultimate strength
  - Local fine mesh FE analysis
  - Advanced buckling analysis



## CSR impact on a 308,000DWT VLCC

Vessel's Name: 308,000DWT VLCC

Builder: CSSC Longxue Shipyard

Designer: MARIC

Year of Delivery: 2010~

No. of vessels: 4

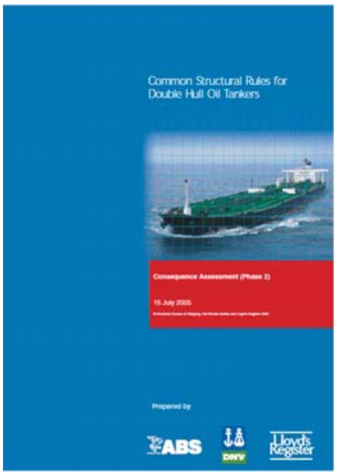
Dimensions ($L_{bp}$/B/D/$T_s$, m):

320/60.0/29.8/21.8

## CSR impact on a 308,000DWT VLCC

**Two challenges:**

1. How to meet the stricter requirement of CSR?
2. How to control the steel weight?

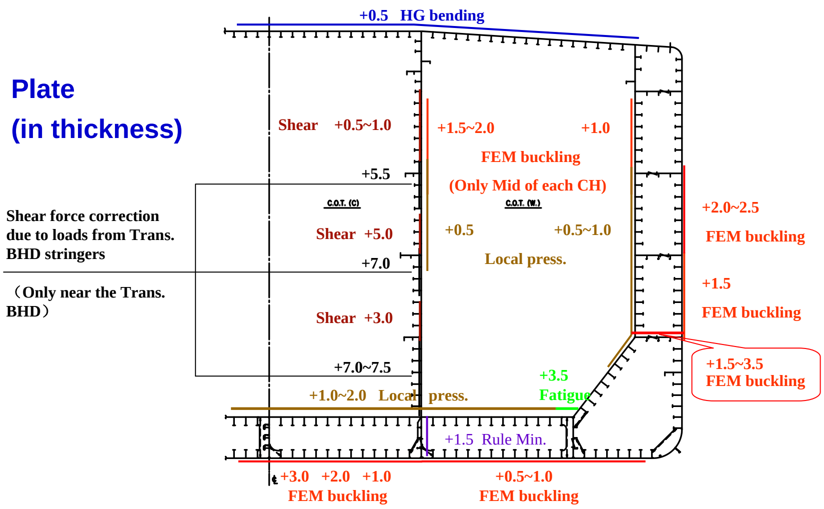



Comparison to the VLCC2 in Consequence Assessment (Phase 2)



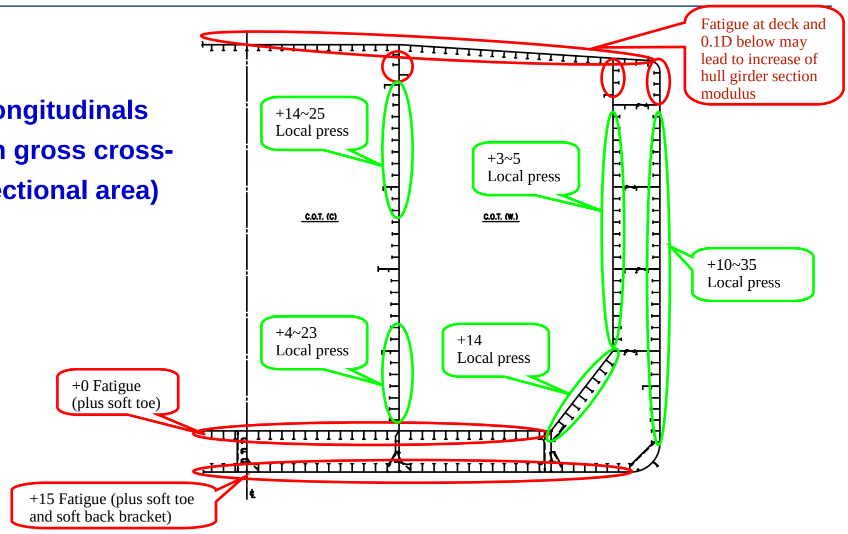
## CSR impact on a 308,000DWT VLCC

**Plate (in thickness)**



## CSR impact on a 308,000DWT VLCC

**Longitudinals (in gross cross-sectional area)**




中国船舶及海洋工程设计研究院
MARINE DESIGN & RESEARCH INSTITUTE OF CHINA (MARIC)

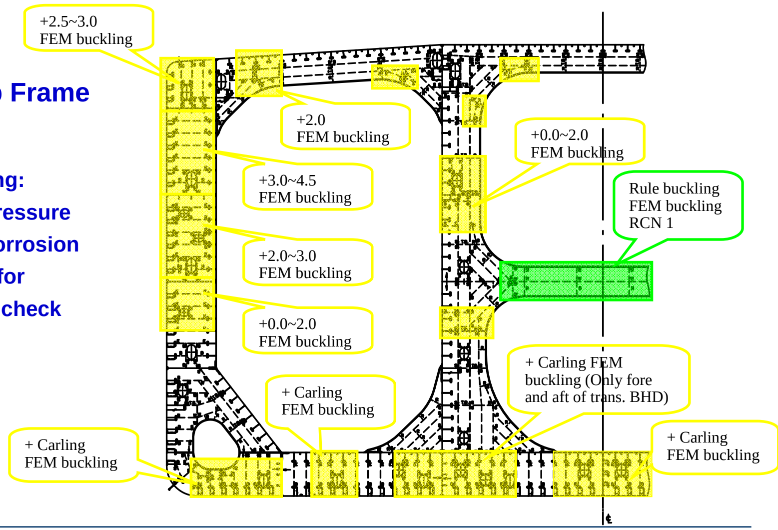
9

## CSR impact on a 308,000DWT VLCC

**TYP. Web Frame**

**FEM buckling:**

- Higher pressure
- Higher corrosion addition for buckling check




中国船舶及海洋工程设计研究院
MARINE DESIGN & RESEARCH INSTITUTE OF CHINA (MARIC)

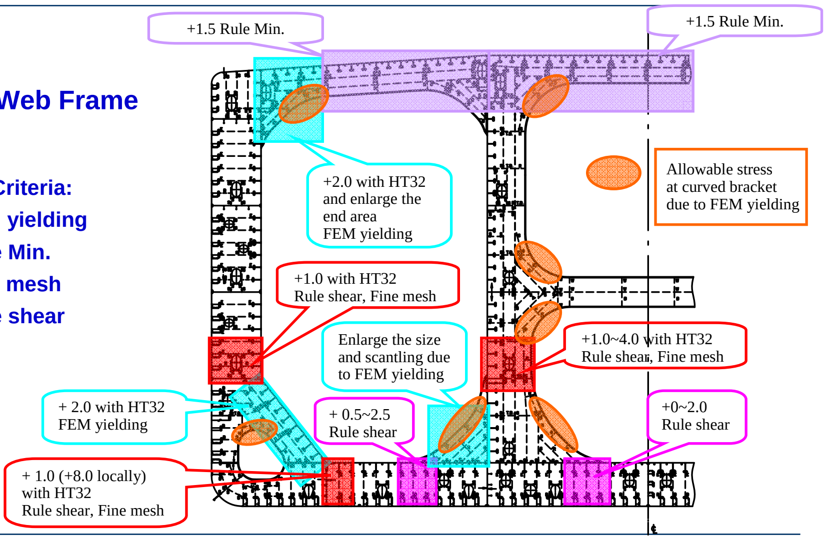
10

## CSR impact on a 308,000DWT VLCC

### TYP. Web Frame

**Other Criteria:**

- FEM yielding
- Rule Min.
- Fine mesh
- Rule shear



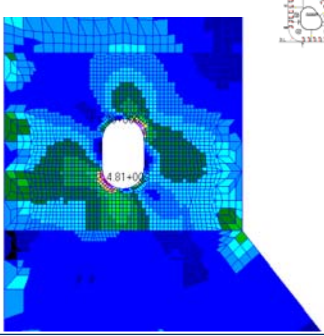




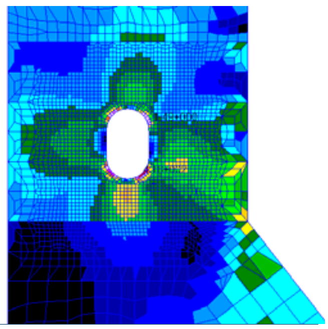
## CSR impact on a 308,000DWT VLCC


### Fine mesh

A1-5a

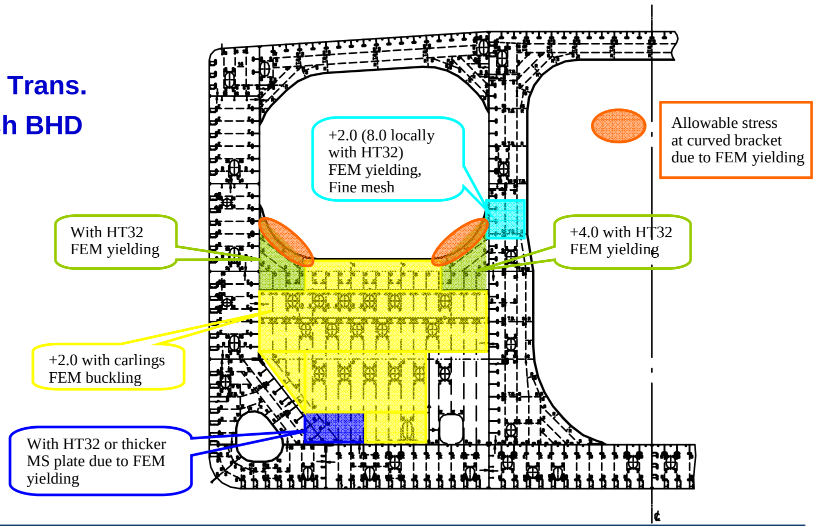


A9



# CSR impact on a 308,000DWT VLCC

## TYP. Trans. Swash BHD

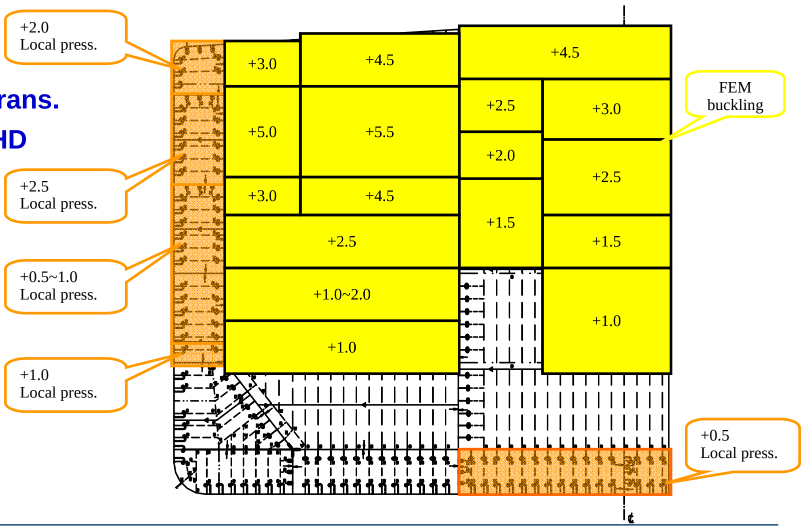



中国船舶及海洋工程设计研究院
MARINE DESIGN & RESEARCH INSTITUTE OF CHINA (MARIC)

13

# CSR impact on a 308,000DWT VLCC

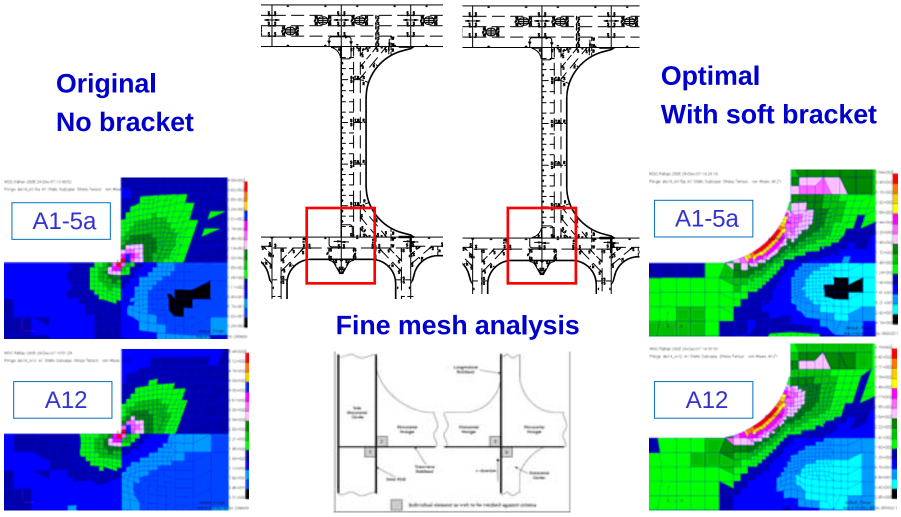
## TYP. Trans. W.T. BHD




中国船舶及海洋工程设计研究院
MARINE DESIGN & RESEARCH INSTITUTE OF CHINA (MARIC)

14

## CSR impact on a 308,000DWT VLCC






## CSR impact on a 308,000DWT VLCC

### For fore end area, aft end area, E/R and P/R area:

- Rule Min. requirement would induce more increasing of scantling, mainly for PSM and W.T. boundaries.
- Local pressure requirement is the second factor for steel weight increasing for tank boundaries due to new load model.
- For upper deck region, green sea load requirement is also the key factor for scantling increasing, especially for PSM.

## CSR impact on a 308,000DWT VLCC

**Conclusion:**

**Total steel weight increase due to CSR:**

| | |
|---|---|
| Cargo Area | +1610t |
| Fore End Area | +95t |
| Aft End Area | +108t |
| Engine Room and Pump Room | +177t |
| Total | +1990t |



## CSR impact on a 308,000DWT VLCC

**From the statistics, it could be found that:**

- Beam sea load cases (5a) and harbor load case (A12) are dominant for advanced buckling check and yielding check for most structural members.
- FEM buckling, FEM yielding and fatigue evaluation are the key factors for increasing the steel weight in cargo hold area due to CSR.
- The weight increment in reference [1] for VLCC is small, while in real design, more steel weight will be increased.
- For fore end, aft end and ER or PR area, the local scantlings will be increased due to CSR minimum thickness requirement, local pressure and green sea load.

## Design experience on CSR VLCC

- **Fatigue evaluation on upper deck structure**
- **Analysis on hull girder shear strength**
- **Cross ties**



## Fatigue evaluation on upper deck structure

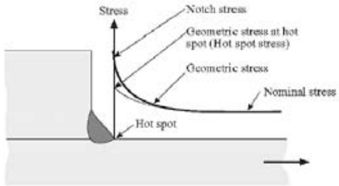
**The recently published statistics indicate a number of defects, especially fractures, occurring in tankers less than 10 years old, where it is found that cracks for the upper deck and stiffeners are greater than that for either side shell or transverse bulkhead.**

| Location | Cracked | Wasted | Deformed | Not Categorized | TOTAL |
|---|---|---|---|---|---|
| Upper deck plate & stiffeners | 21.2% | 3.8% | 0.7% | 0.2% | 25.9% |
| Side shell plate & stiffeners | 11% | 6.3% | 3.1% | 0.2% | 20.6% |
| Transverse bulkhead plate & stiffeners | 11.1% | 1.9% | 0.5% | 1.2% | 14.7% |
| Longitudinal bulkhead plate & stiffeners | 8.4% | 3.4% | 0.3% | 0.1% | 12.2% |
| Inner bottom plate & stiffeners | 5.8% | 3% | 0.1% | 0.5% | 9.4% |
| Bottom shell plate & stiffeners | 3.4% | 3.6% | 0.3% | 1.3% | 8.6% |
| Vertical web plate in double side | 1.6% | | | | 1.6% |
| Inner hull longitudinal bulkhead plate & stiffeners (including hopper) | 0.5% | 0.5% | | 0.1% | 1.1% |
| Vertical web and face plate of longitudinal bulkhead | 0.9% | | | | 0.9% |
| Vertical web and face plate of transverse bulkhead stringers | 0.5% | | 0.2% | | 0.7% |
| Web and face plate of deck transverse | 0.1% | | | | 0.1% |
| Floors | 0.5% | | 0.2% | | 0.7% |
| Other | 2.4% | | 0.5% | | 2.9% |
| Not stated | 0.6% | | 0.5% | 0.1% | 1.2% |
| | 67.4% | 22% | 6.4% | 3.7% | ~ 100% |

**Source: TSCF 2007 Shipbuilders Meeting paper**

## Fatigue evaluation on upper deck structure

- For upper/strength deck region, the nominal stress ranges are only induced by hull girder wave bending moments.




- Although stress concentration factors are not expressed clearly in CSR for tankers (actually they are included in the S-N curve), such values can be found in Class Rules.
- By Classification Factor, different S-N curves can be unified as one S-N curve.

| S-N curve | B | C | D | E | F | F2 | G |
|---|---|---|---|---|---|---|---|
| Classification Factor | 0.83 | 1.02 | 1.44 | 1.62 | 1.92 | 2.19 | 2.63 |



## Fatigue evaluation on upper deck structure

- With the actual nominal stress range for deck structure calculated by empirical CSR formula or hydrodynamic analysis, the allowable fatigue factor [K] can be achieved by setting fatigue damage DM=1.

$$\sigma_v = \frac{M_{wv-v-amp}}{Z_{v-net75}} 10^{-3} \qquad \sigma_h = \frac{M_{wv-h-amp}}{Z_{h-net75}} 10^{-3}$$

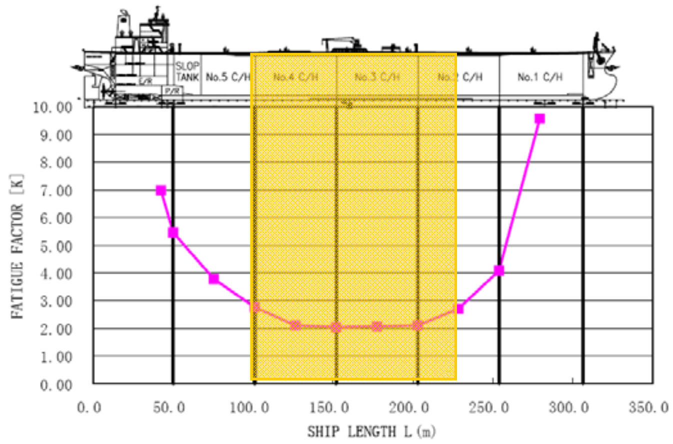
$$S = f_{SN} \left| f_1 S_v + f_2 S_h \right|$$

$$DM_i = \frac{\alpha_i N_L}{K_2} \frac{S_{Ri}^m}{(\ln N_R)^{m/\xi}} \mu_i \Gamma\left(1 + \frac{m}{\xi}\right)$$

$$[K] = \frac{\Delta\sigma_{perm-nominal}}{\Delta\sigma_{actual-nominal}} = K_g K_w$$

## Fatigue evaluation on upper deck structure

Typical diagram of fatigue factor [K] for deck region in C.L. section:

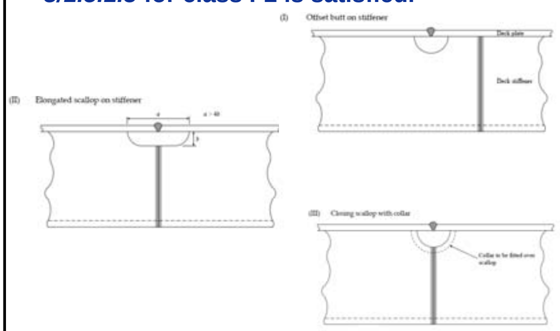





## Fatigue evaluation on upper deck structure

# Case 1: Details of block joint in deck longitudinals

**CSR APPENDIX C/1.6.1.1 Scallops in way of block joints in the cargo tank region, located on the strength deck, and down to 0.1*D* from deck corner are to be designed according to *Figure C.1.12* unless the specification in *Section 8/1.5.1.3* for class F2 is satisfied.**




**For 308K_VLCC:**

**Within 0.4L amidships:**

**$[K]_{min}=2.0$**

**Outside 0.4L amidships:**

**$[K]_{min}=3.0$**

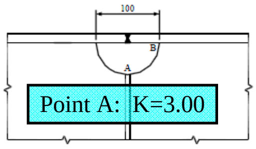
**Outside 0.6L amidships:**

**$[K]_{min}=4.5$**

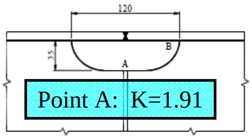
## Fatigue evaluation on upper deck structure

### Case 1: Details of block joint in deck longitudinals

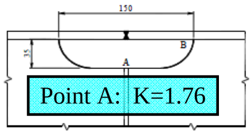
a=2b

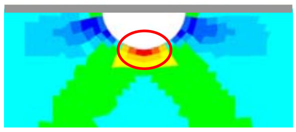



2b<a<4b

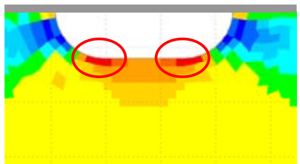



a>4b



Not OK
Within 0.6L
amidships

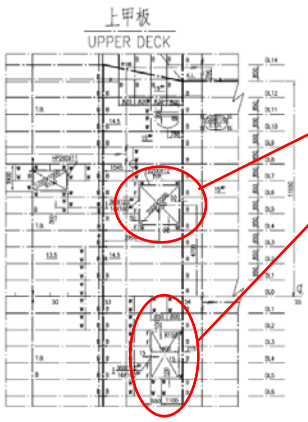


Not OK
Within 0.4L
amidships



## Fatigue evaluation on upper deck structure

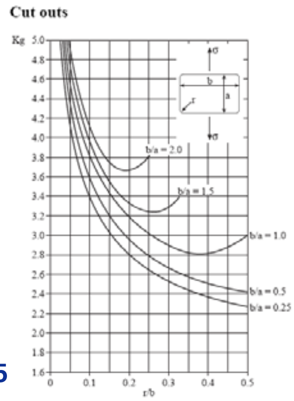
### Case 2: SCF for rounded rectangular holes




K=4.0

K=4.8

For 308K_VLCC:
At the region of P/R
front Trans. BHD:
$[K]_{min}$=5.5



## Fatigue evaluation on upper deck structure

### Case 3: Fatigue section modulus

- The preliminary "fatigue section modulus" verification (Section 8/1.5.3) provided by CSR is a simplified fatigue control measure against the dynamic hull girder stresses in the longitudinal deck structure.

$$Z_{v-fat-\min-net50} = \frac{M_{wv-hog} - M_{wv-sag}}{1000 R_{al}}$$

- The greater value of section modulus at deck side, the lower nominal stress for deck structure could be found, and then the greater value of [K] could be achieved. That is to say, the greater value of [K], the better fatigue life could be estimated.



## Analysis on hull girder shear strength

### Shear flow:

$$q_v = f_i \left( \frac{q_{1-net50}}{I_{v-net50}} \right) \cdot 10^{-9} \Rightarrow \frac{dq_v}{q_v} = \frac{df_i}{f_i} + \frac{dq_{1-net50}}{q_{1-net50}} - \frac{dI_{v-net50}}{I_{v-net50}}$$

### Vertical shear strength:

$$Q_{vij-net50} = \frac{\tau_{ij-perm} t_{ij-net50}}{1000 q_{vij}}$$

$$\frac{dQ_{vij-net50}}{Q_{vij-net50}} = \frac{d\tau_{ij-perm}}{\tau_{ij-perm}} + \frac{dt_{ij-net50}}{t_{ij-net50}} - \frac{dq_{vij}}{q_{vij}}$$

## Analysis on hull girder shear strength

**Case 1: No changes for plate thickness, but increase the permissible shear stress of the plate *ij***

$$\frac{dQ_{vij-net50}}{Q_{vij-net50}} = \frac{d\tau_{ij-perm}}{\tau_{ij-perm}}$$

**Conclusion: Using higher tensile steel is the most effective method to increase the vertical shear capacity for the longitudinal bulkheads between cargo tanks.**



## Analysis on hull girder shear strength

**Case 2: Only increase the plate thickness for plate *ij*, no changes for the material**

**For plate *ij*:**

$$\frac{dQ_{vij-net50}}{Q_{vij-net50}} = \frac{dt_{ij-net50}}{t_{ij-net50}} - \frac{dq_{vij}}{q_{vij}}$$

**For plate *gh*:**

$$\frac{dQ_{vgh-net50}}{Q_{vgh-net50}} = -\frac{dq_{vgh}}{q_{vgh}}$$

**Conclusion: Increasing plate thickness for plate *ij* will result in the increment of shear flow. Therefore, for plate *gh*, the vertical shear capacity will be decreased.**

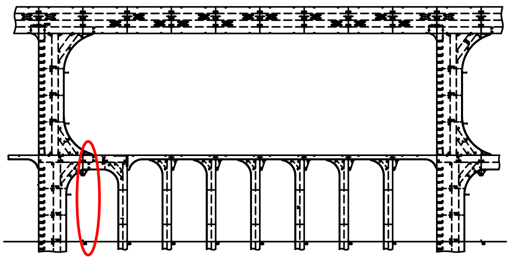
## Cross ties

- For improving shipyard technology and owner's convenience to tank wash, the current trend is to set the cross ties in center cargo tank.
- PMA requirement: for ships having cross ties in center cargo tank which are 6m or more above tank bottom, a transverse PMA on the cross ties providing inspection of the tie flaring brackets at both sides of the tank, with access from one of the longitudinal PMA.
- According to buckling requirement of CSR, not only the column buckling mode, but also the torsional buckling mode and the interaction between them are to be checked.



## Cross ties

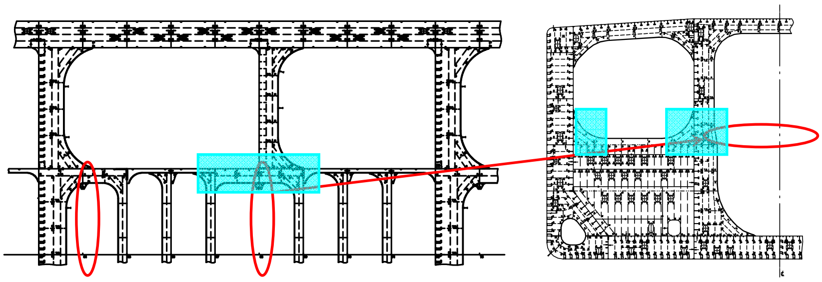
The conventional arrangement of cross ties in center cargo tank:



- The omitted cross tie is due to the horizontal stringer on the transverse watertight bulkhead.
- Longitudinal PMA is not integrated in the structural members.

## Cross ties

**The current typical arrangement of cross ties in center cargo tank:**

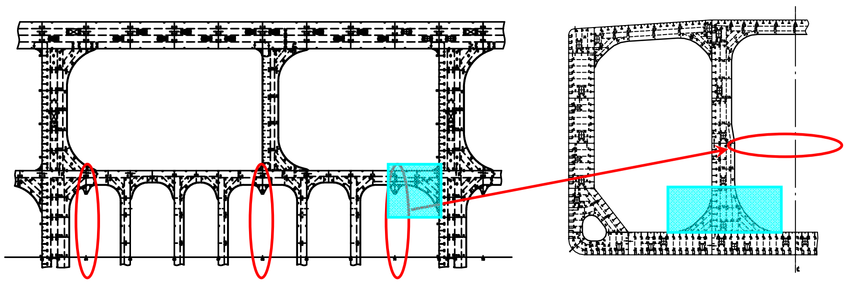


- One more cross tie is omitted in way of transverse swash bulkhead arranged in wing cargo tanks.
- In this case, the horizontal stringers on swash bulkhead and the enlarged local longitudinal stringers are to be designed carefully.
- Longitudinal PMA may be integrated in the structural members or not.



## Cross ties

**The arrangement of cross ties in 308K_VLCC:**



- Another cross tie is omitted 1 frame aft or forward from the transverse bulkhead considering the enlarged longitudinal PMA stringers.
- The end of longitudinal PMA is enlarged and the lower portion of vertical transverse where the omitted cross tie locates is reinforced.
- Longitudinal PMA is to be integrated in the structural members.

## Cross ties (Rule changes)

### RCN 1 of CSR to July 2008 version for cross ties:

**Section 8/2.6.8.1:** $\eta_{ct}$ utilisation factor, to be taken as:

= ~~0.50~~ 0.65 for acceptance criteria set AC1

= ~~0.60~~ 0.75 for acceptance criteria set AC2

**Section 9/2.2/Table 9.2.2:**

| | |
|---|---|
| Pillar buckling of cross tie structure | $\eta \leq$ ~~0.50~~ 0.75(load combination S + D)<br>$\eta \leq$ ~~0.40~~ 0.65(load combination S) |

**Section 10/3.5.1.3:** Column buckling capacity for cross tie shall be calculated using $f_{end}$ equal to 2.0 and span as defined in *8/2.6.8.1*

*RCN 1 to July 2008 version (effective from 1 February 2010)*

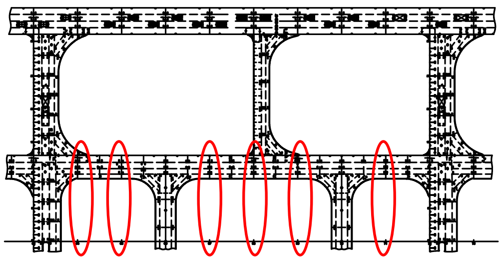
**Section 10/3.5.1.4:** Elastic torsional buckling capacity for cross tie shall be calculated using $f_{end}$ equal to 2.0 and span as defined in *8/2.6.8.1*

*RCN 1 to July 2008 version (effective from 1 February 2010)*



## Cross ties

### New arrangement of cross ties in the future (research stage):



- Longitudinal PMA is to be integrated in the structural members and is to be enlarged more than required.
- Only two cross ties are arranged between transverse swash bulkhead and transverse watertight bulkhead.
- New centrosymmetric type of cross tie with HT32 steel used.

## Cross ties

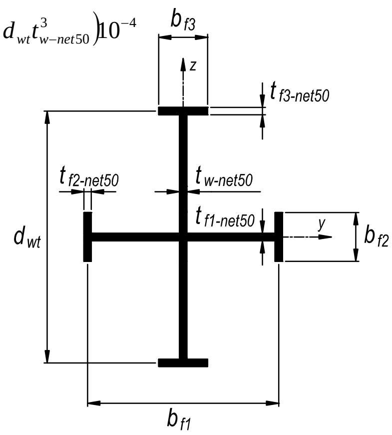
### New centrosymmetric type of cross tie:

$$I_{sv-net50} = \frac{1}{3}\left(b_{f1}t_{f1-net50}^{3} + 2b_{f2}t_{f2-net50}^{3} + 2b_{f3}t_{f3-net50}^{3} + d_{wt}t_{w-net50}^{3}\right)10^{-4}$$

$$y_0 = 0$$

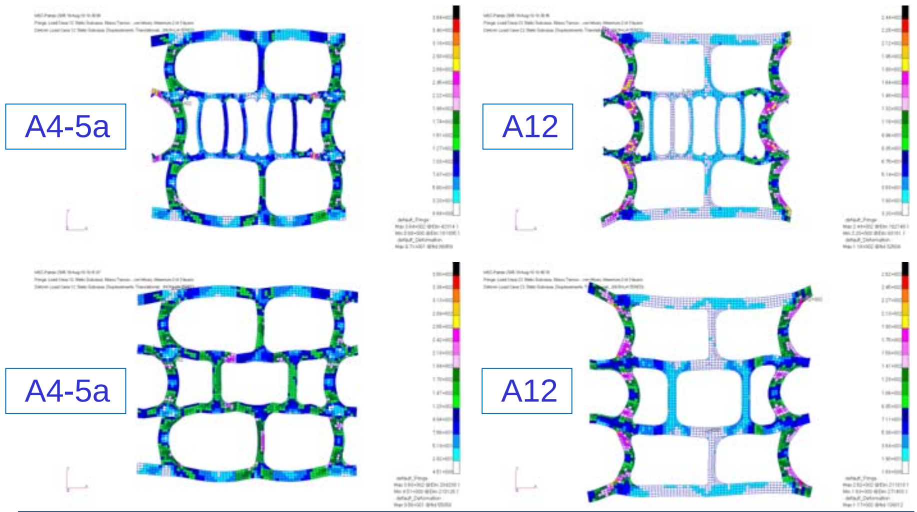
$$z_0 = 0$$

$$C_{warp} = \frac{b_{f1}^{2}b_{f2}^{3}t_{f2-net50} + d_{wt}^{2}b_{f3}^{3}t_{f3-net50}}{24}10^{-6}$$



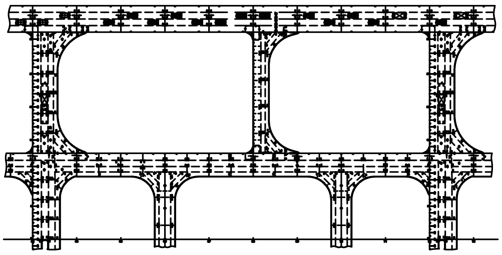



## Cross ties



## Cross ties

New arrangement of cross ties in the future (research stage):



**Feasible choice!**

- Can meet the scantling requirement and coarse mesh analysis of CSR.
- The steel weight would be almost same with other choices excluding the increasing due to the integration of longitudinal PMA.
- Fine mesh or detail analysis will be carried out in the future.
- Will be submitted for Class for plan approval.



## Design Experience on CSR VLCC

# Conclusions on MARIC's design experience:

I. To avoid the failures due to fatigue in upper deck region, the evaluation of maximum allowable stress range or fatigue factor [K] is feasible for the shipyard to choose, check or confirm the suitable structural details during construction.

II. Using the higher strength steel is the most effective method to increase the vertical shear capacity for the longitudinal bulkheads between cargo tanks.

III. When considering the enlarged longitudinal PMA girder, the arrangement and section of cross tie could be optimized for improving shipyard technology and owner's convenience to tank wash.


Please share our design experience!
Thank You for Your Attention!
中国船舶及海洋工程设计研究院
MARINE DESIGN & RESEARCH INSTITUTE OF CHINA (MARIC)
41