Annual report of *ASEF/TWG/SWG2* on UR S11A "*Longitudinal Strength Standard for Container Ships*"

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Activities of ASEF/TWG/SWG2

- ***TWG/SWG2*** had been organized with the establishment of ***ASEF*** on 26 Nov. 2015 to exchange information and views mainly on **IACS UR S11A** and **UR S34**, which were to be uniformly implemented by IACS Societies for container ships contracted for construction on or after 1 July 2016.
- **12** ***Experts*** have been registered with ***TWG/SWG2*** by **4** ***ASEF*** members by 17 Oct. 2016 .
- Before 1 July 2016, ***ASEF*** and CESS used a variety of forms to communicate with IACS (by formal letter or face-to-face meeting), but due to great work load imposed on IACS in respect of the GBS, IACS agreed to continue with their efforts to expand technical requirements for container ship (CV) strength and deal with shipbuilders' concerns in order of priority, including **hull girder ultimate strength**, **whipping** etc.
- So far consequence assessments for various typical container ships have been carried out by ***TWG/SWG2 experts*** in order to illustrate the detail impact by new URs and find other technical issues to be discussed.

Shipbuilders' concerns on UR S11A and answers from IACS

S11A.5.2 Hull girder ultimate bending moments

$$M = \gamma_S M_S + \gamma_W M_W$$

- γ_S : partial safety factor for SWBM
  = 1.0, the same as that in CSR
- ***Shipbuilders' concerns***:
  - Although Shipper's declaration of **container weight** is made mandatory by IMO, **efficacy** is still in question and SWBM of a CV is more difficult to control than that of a BC or OT for shipowners.
  - The **over loading** cases in hull girder ultimate strength are to be considered.
- ***Answers from IACS***:
  - IACS does not have access to any distributions on the increase in SWBM caused by unfavorable distributions of containers with incorrect weight declaration.

- γ_W : partial safety factor for WBM
  = 1.2, the same as that in CSR
- ***Shipbuilders' concerns***:
  - **5** knots speed for CVs at rough sea seems rather risky due to the much slender hull form and the much bigger propulsion power of CVs.
  - What is the background from IACS to use **5** knots speed for CVs in direct wave load analysis?
- ***Answers from IACS***:
  - The 1.2 value selected, was already being used for CVs by several Class Societies, and not made only on CSR equivalency.

Shipbuilders' concerns on UR S11A and answers from IACS

S11A.5.4 Acceptance criteria

$$M \leq \frac{M_U}{\gamma_M \gamma_{DB}}$$

- γ_M : partial safety factor covering material, geometric and strength prediction uncertainties.

  = 1.05, less than 1.1 defined in CSR
- ***Shipbuilders' concerns***:
  - Why the value for CVs is smaller than that set for BC & OT although calculation method is identical.
- ***Answers from IACS***:
  - The use of 1.05 is considered to be reasonable on a current practice basis.
  - In the investigation report for the MOL Comfort, the factor of 1.05 is found to be reasonable to account for non-linear methodology.
  - A combined safety factor (material inconsistency and DB effect) should be 1.2≈1.05*1.15.

- γ_{DB} : partial safety factor covering the effect of local stress working in double bottom structure (DB effect)

  = 1.15 for hogging condition

  = 1.0 for sagging condition
- ***Shipbuilders' concerns***:
  - The reason of the value set of 1.15 in hogging condition is not clear in TB document.
  - Reduction by γ_{DB} may be overestimated.
- ***Answers from IACS***:
  - A combined safety factor (material inconsistency and DB effect) of 1.2≈1.05*1.15 is reasonable in MOL C report.

Shipbuilders' concerns on UR S11A and answers from IACS

S11A.6 Additional requirement for large container ships

- ***Shipbuilders' concerns***:
  - Functional requirements for "yielding and buckling assessment" and "whipping" are provided only. As a consequence, there will be difference in actual requirements to be developed by each classification society, which leads to difference in safety level.
  - Whipping effect will be incorporated into hull girder ultimate strength assessment at each classification society's own discretion.
  - The effect of whipping on WBM should be specified quantitatively by IACS.

Whipping effect consideration:

ABS: $\gamma_S M_{SW} + \gamma_W \cdot (ku \cdot M_w) \le M_U / (\gamma_M \gamma_{DB})$

DNVGL: $\gamma_s M_{SW} + M_{WV}\left(\gamma_W + \left(\gamma_{WH} - \gamma_W\right)\gamma_{dU}\right) \le \frac{M_U}{\gamma_M \gamma_{DB}}$

LR: $M_{SS} + \gamma_W \cdot \left(f_{fS-W} M_{w0}\right) \le M_{US} / \gamma_R$

$M_{SH} + \gamma_W \cdot \left(f_{fH-W} M_{w0}\right) \le M_{UH} / \gamma_R$

- ***Answers from IACS***:
  - IACS is progressing with the setting up of **a new Project Team** to look at gradually expanding the functional requirement on whipping, and improve consistency between members.
  - Require a significant amount of work, but as a first step, providing more detailed and technical functional requirement is considered to be the best way forward at this point in time.

Consequence assessment for UR S11A

Comparison between UR S11A and UR S11

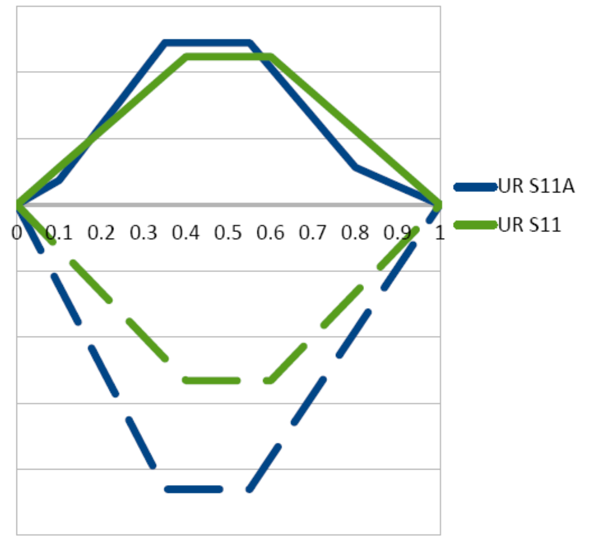
Item	UR S11 (Rev.8 June 2015)	UR S11A (2015)
Application	All ships	Container ships only
Scantlings based on	Gross scantling (except buckling)	Net scantling concept
Still water loads	Defined for all ships	Reference to UR S1
Wave loads	VWBM and VWSF	Revised load formulations
Stiffness criterion	Min. moment of inertia based on ship dimensions	Min. moment of inertia based on bending moment
Yielding stress criteria	Permissible bending or shear stress	Von mises yielding criteria
Bending strength	Min. sectional modulus	Bending stress evaluation
Shear strength	Min. plate thickness	Shear stress evaluation
Buckling strength	Linear buckling considering Johnson-Ostenfeld correction	Prescriptive approach following CSR
Hull girder ultimate strength	No requirement	Following CSR approach when no whipping effect
Functional requirements for large ships	No requirement	Addressing consideration of local and bi-axial (in-plane) loads and whipping effect

Consequence assessment for UR S11A

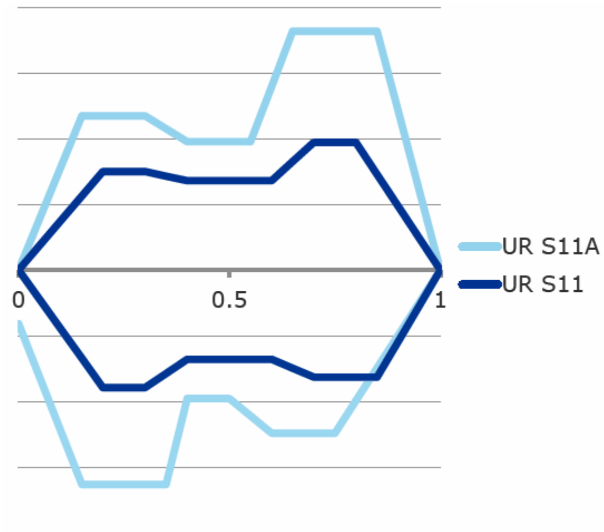
Wave bending moment and shear force

- ***Philosophy* behind UR S11A**:
  - Follows as far as possible the philosophy of CSR.
  - Based on non-linear load computations of more than 120 CVs and two loading conditions for each ship.
- ***Hypothesis* in UR S11A**:
  - Sea states described by the **North Atlantic** scatter diagram from **IACS Rec. No. 34**
  - All heading with a step of 15 degrees and **even probability distribution**
  - Ship speed equal to **5 knots**
  - Extreme response corresponding to one exceedance every 25 years (probability of exceedance of about 10^{-8})
- ***New formula*** made of the following parameters:
  - Routing factor, f_R **= 0.85**
  - Scale factor: L^3 for bending moment; L^2 for shear force
  - Wave parameter C
  - Non-dimensional formulation
  - Non-linear factor

Vertical wave bending moment



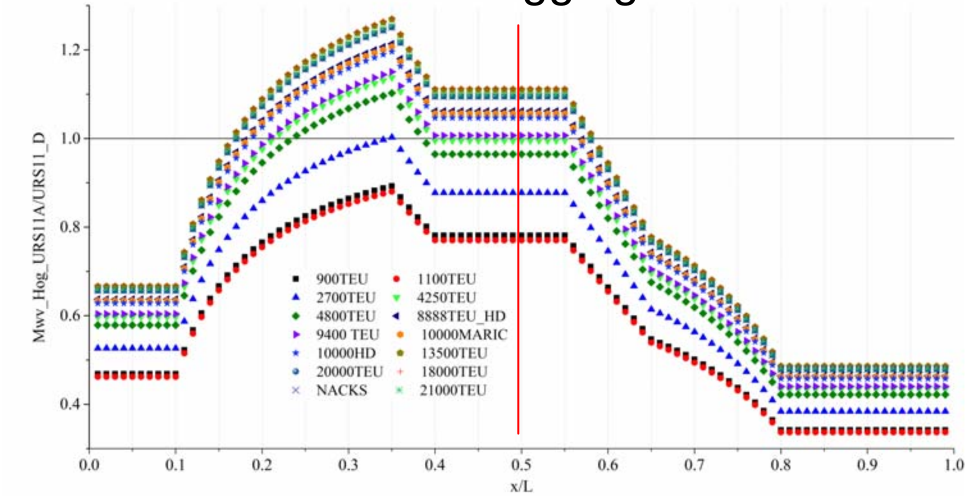
Vertical wave shear force



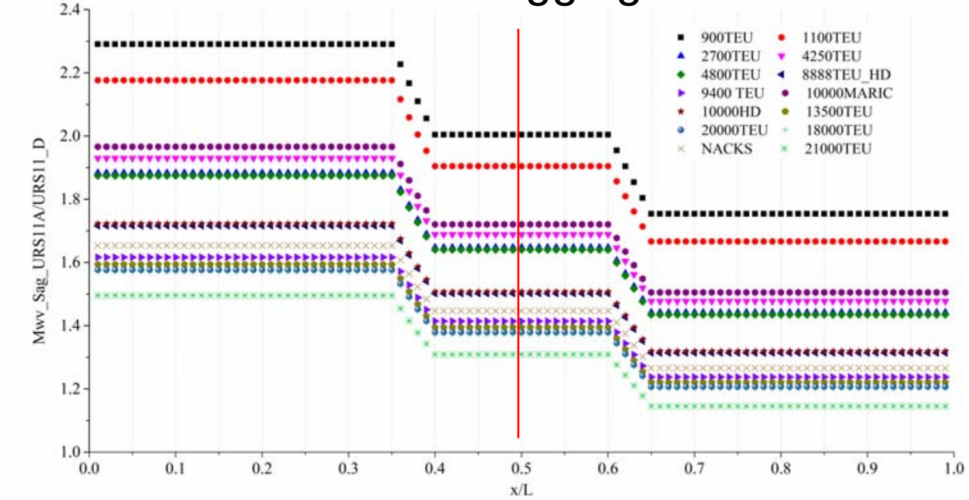
Consequence assessment for UR S11A

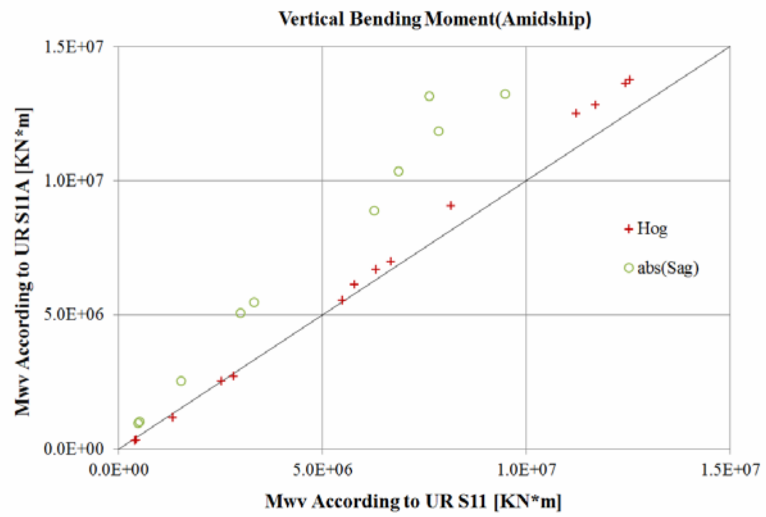
Wave bending moment

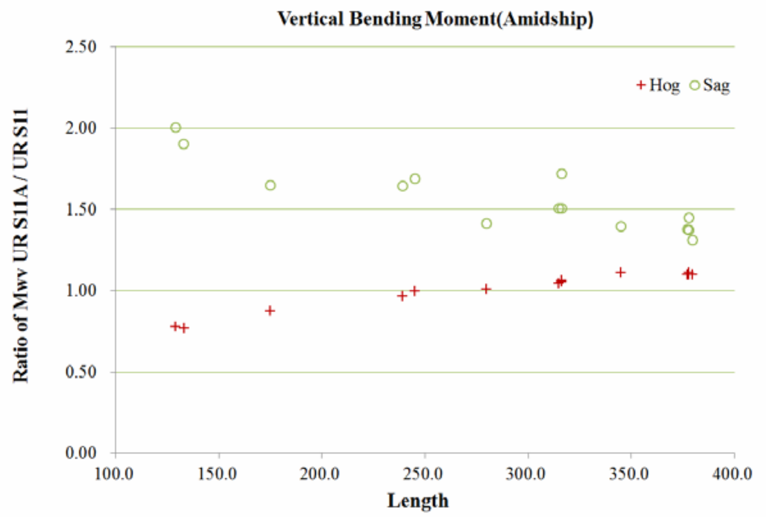
Vertical WBM in Hogging condition



Vertical WBM in Sagging condition



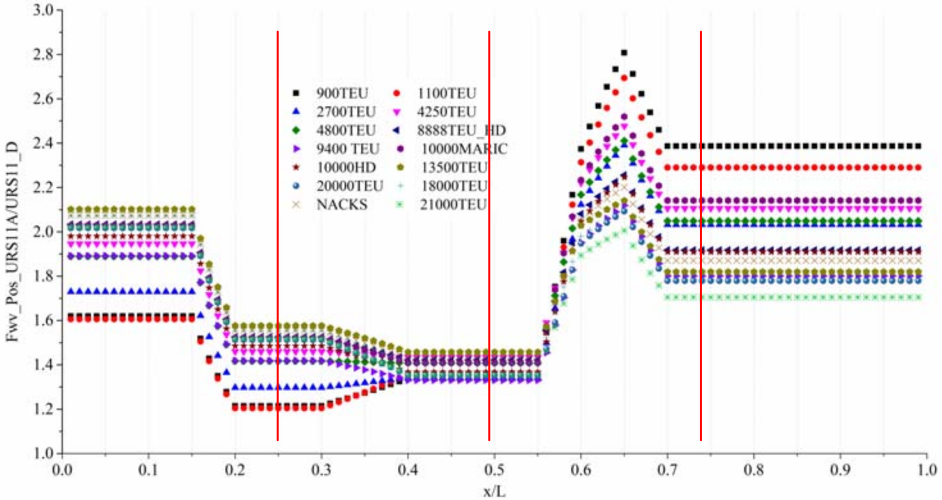




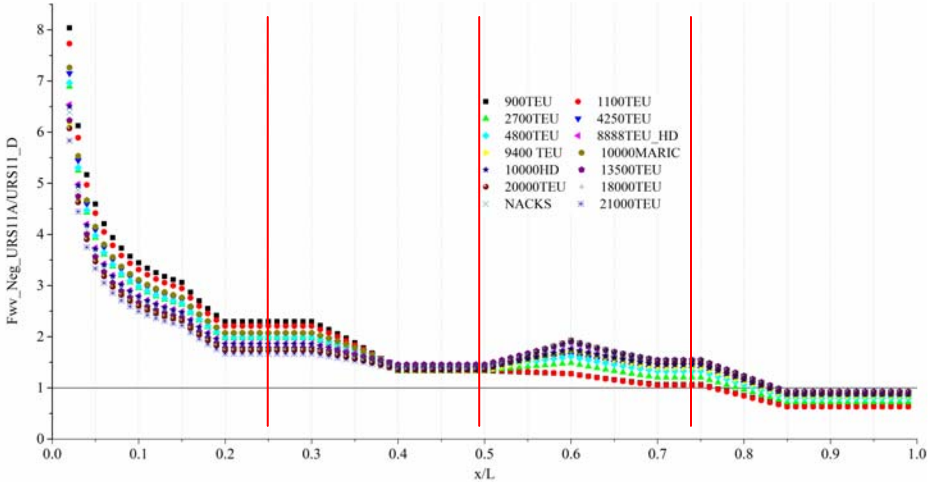
Consequence assessment for UR S11A

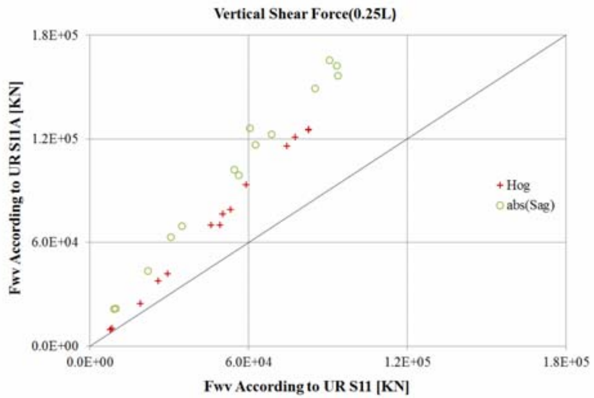
Wave shear force

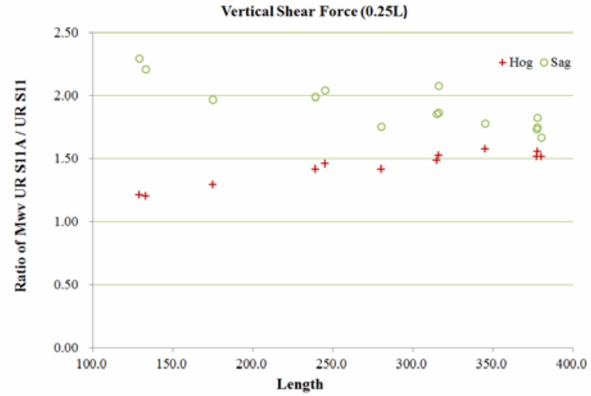
Vertical WSF in Hogging condition

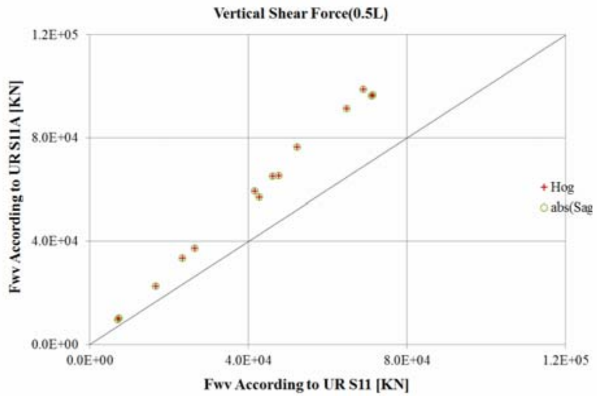


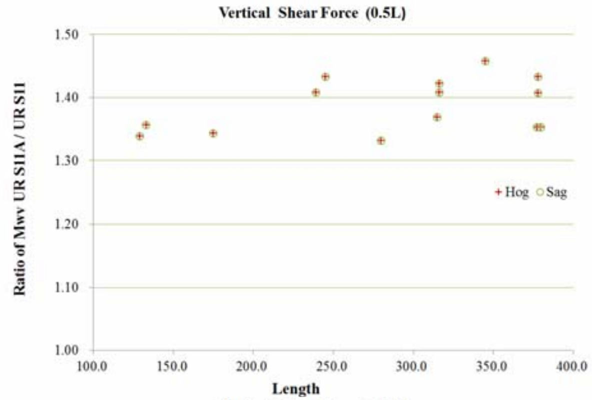
Vertical WSF in Sagging condition

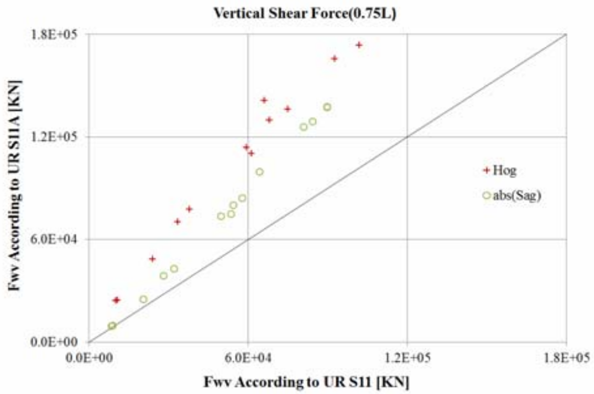


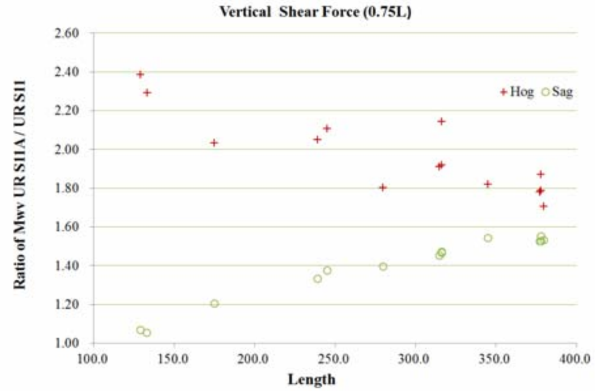








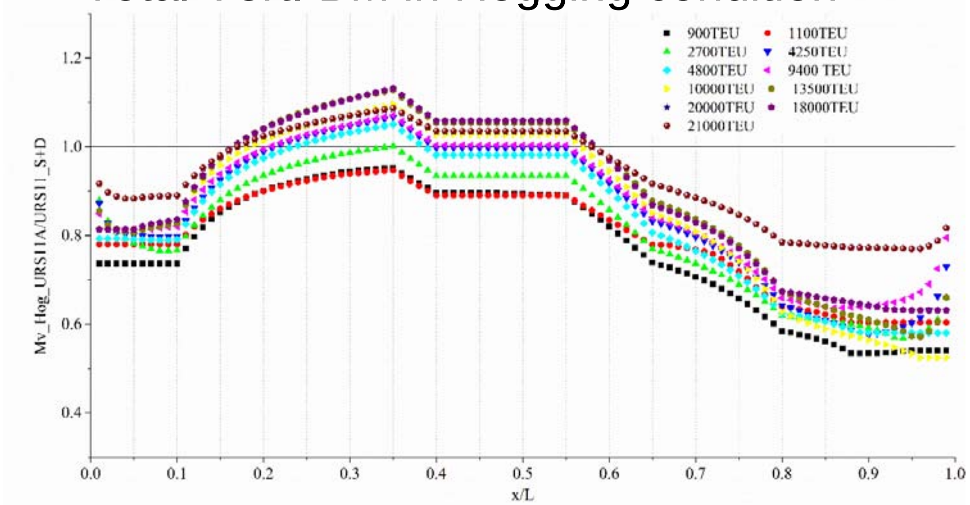




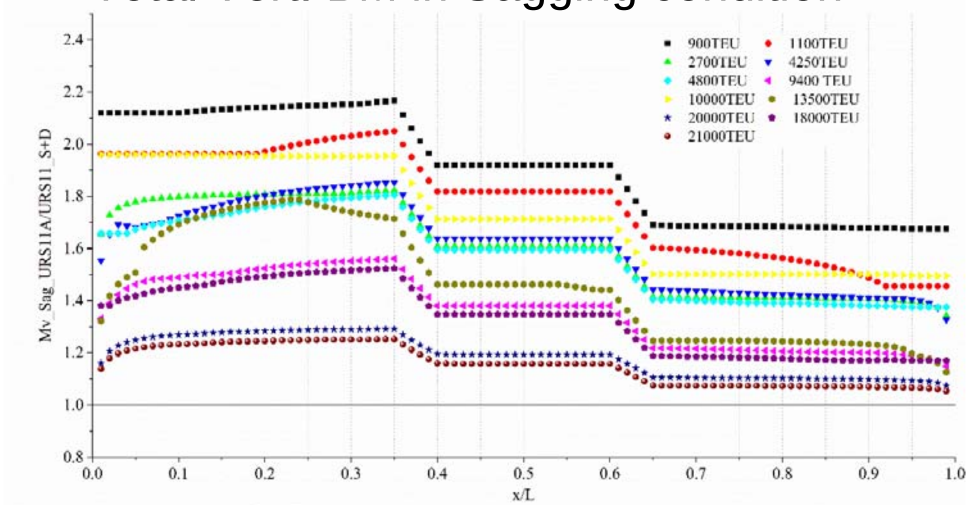
Consequence assessment for UR S11A

Hull girder total bending moment and shear force (Still water + wave)

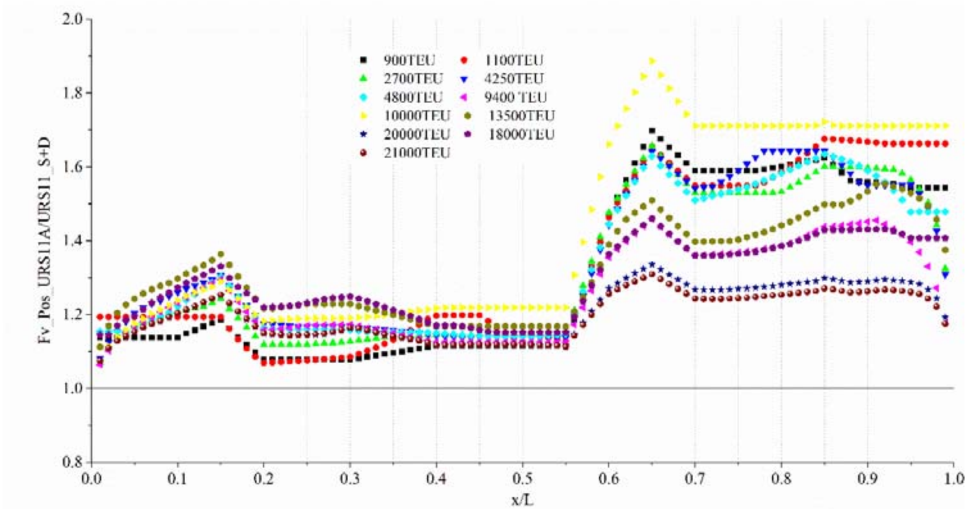
Total Vert. BM in Hogging condition



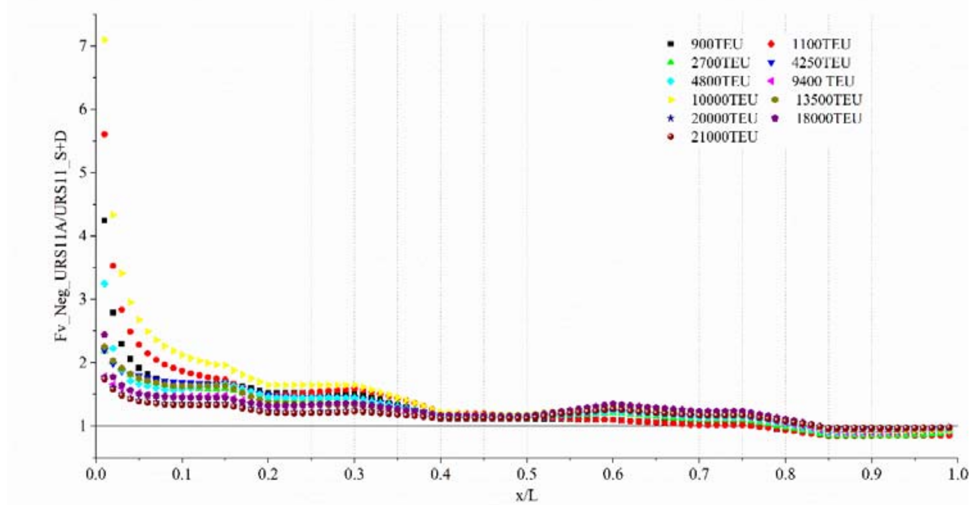
Total Vert. BM in Sagging condition



Total Vert. SF in Hogging condition

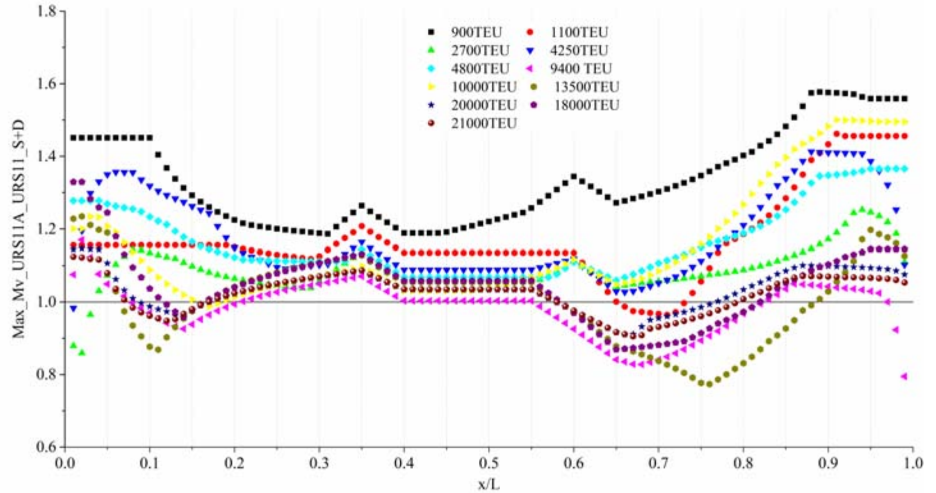


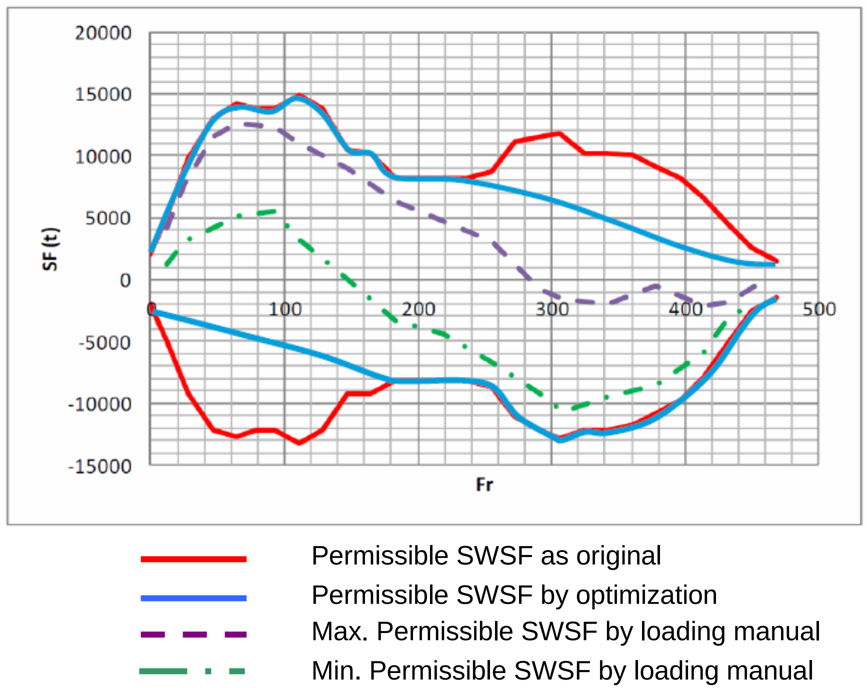
Total Vert. SF in Sagging condition



Consequence assessment for UR S11A

- **Hull girder total bending moment**:
  - If keep SWBM in sagging condition as original design value, hull girder total bending strength will be determined by sagging condition, which is unreasonable.
  - It is suggested to shipbuilding industry that **the design SWBM in sagging condition could set to positive with the value equal to minimum hogging SWBM**.
- **Hull girder total shear force**:
  - The increase of total shear force is significant due to the great increase of wave shear force by UR S11A.
  - The **optimization** for loading manual and loading computer will be carried out, but:
    - ✓ Consider the **operation flexibility** of owner
    - ✓ How to **accurately model SWSF**?





Consequence assessment for UR S11A

Hull girder strength evaluation

- **Several container ships are to be investigated by *TWG/SWG2* members**:
  - 2700TEU CV, evaluated by MARIC (China)
  - 4250TEU CV, evaluated by SJTU (China) (no scantling adjustment)
  - 9000TEU CV, evaluated by Japan Marine United Corporation (JMU) (Japan)
  - 9300TEU CV, evaluated by STX O&S (Korea)
  - 9400TEU CV, evaluated by MARIC (China)
  - 13500TEU CV, evaluated by Hudong-zhonghua (China)
  - 20000TEU CV, evaluated by MARIC (China)
- **Consequence assessment based on**:
  - For feeder vessels, minimum SWBM set to positive; For other container ships, keep minimum SWBM values as original design values, or set to 0 if found hull girder total bending strength determined by sagging condition.
  - Still water curve no optimization, same as original design distribution
  - Material could be increased to maximum HT36
  - No scantling optimization
  - Only prescriptive calculation carried out, no FE analysis (except 4250TEU CV), i.e. no consideration of the possible decrease of scantling due to prescriptive requirement

Consequence assessment for UR S11A

Hull girder strength evaluation

- **Strength assessment including**:
  - Section modulus
  - Yielding (Bending)
  - Yielding (Shear)
  - Plate buckling
  - Stiffener buckling
  - Ultimate strength (**no whipping effect**)

	0.25L	0.35L	0.5L	0.65L	0.7L	0.75L
Section modulus	OK	OK	OK	OK	OK	OK
Yielding (Bending)	OK	OK	OK	OK	OK	OK
Yielding (Shear)	OK	OK	OK	OK	NG	NG
Plate buckling	NG	NG	OK	NG	NG	NG
Stiffener buckling	NG	NG	NG	OK	OK	NG
Ultimate strength	OK	OK	OK	OK	OK	OK

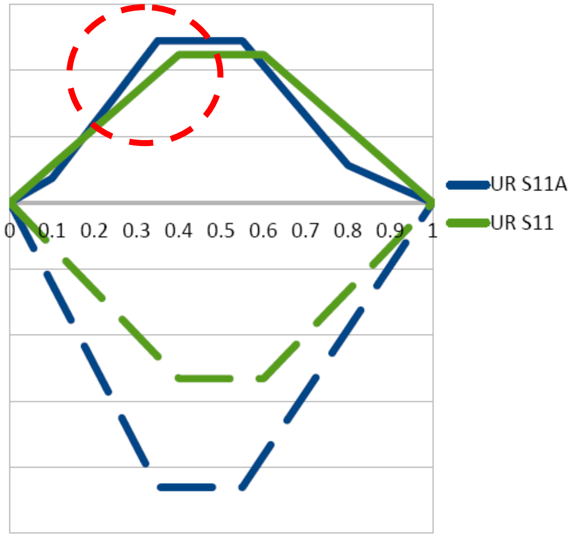
Source: CA report of 9000TEU CV by JMU, Japan

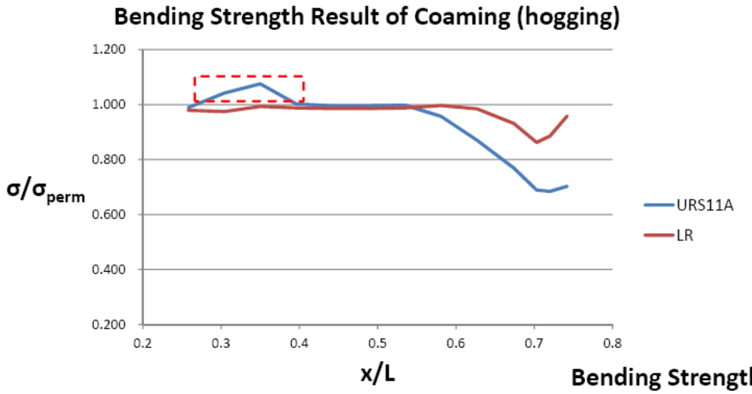
- **Scope along ship length**:
  - Normally 0.25L~0.75L

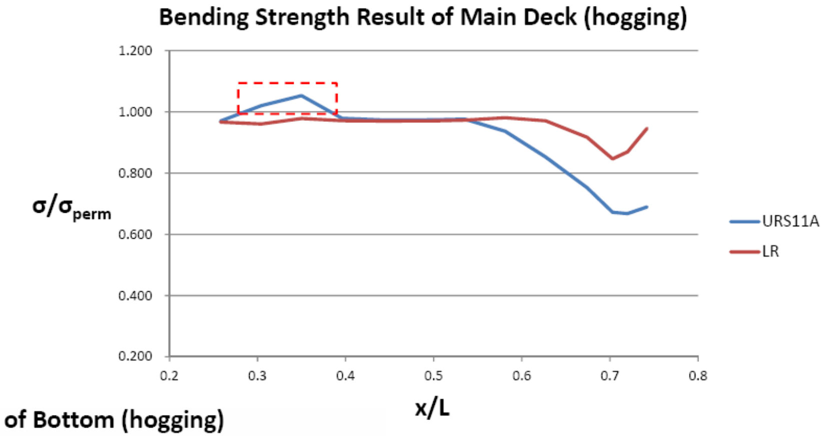
Consequence assessment for UR S11A

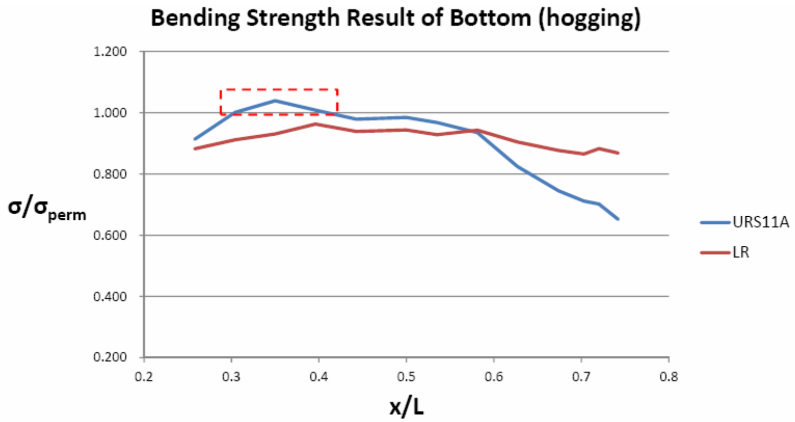
Hull girder strength evaluation

- **The common problems found during CA:**
  - Hull girder **bending** strength:
    - ✓ Only found for CVs with little margin for bending strength by pre-UR S11A requirement
    - ✓ Generally in the region of 0.3L~0.4L







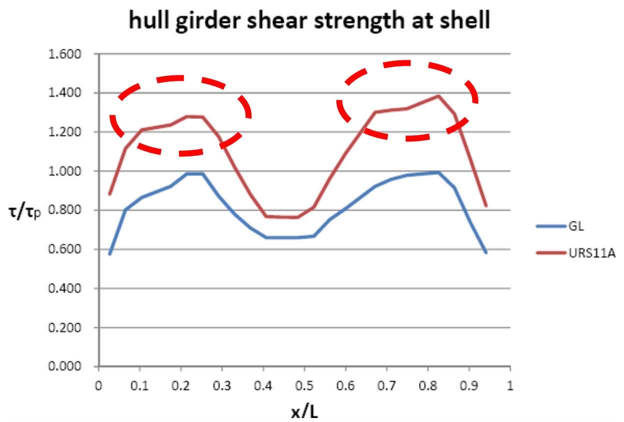


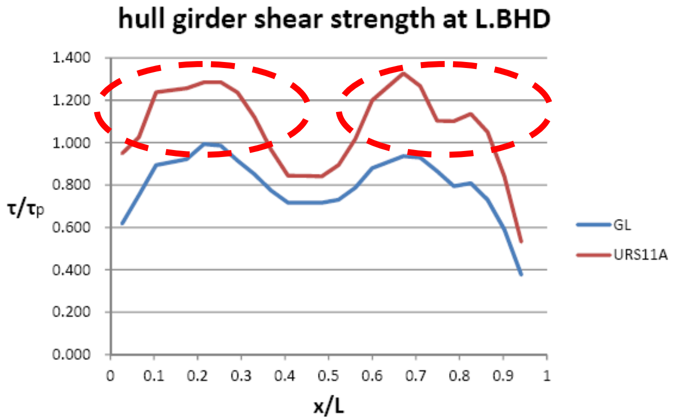
Source: CA report of 13500TEU CV by Hudong-zhonghua

Consequence assessment for UR S11A

Hull girder strength evaluation

- **The common problems found during CA:**
  - Hull girder **shear** strength





Source: CA report of 20000TEU CV by MARIC

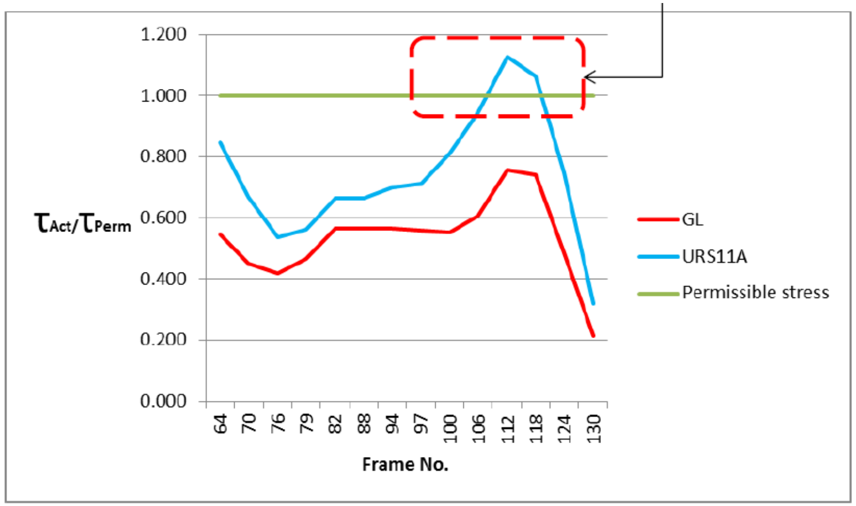
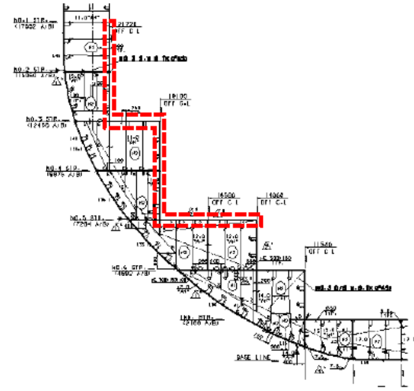
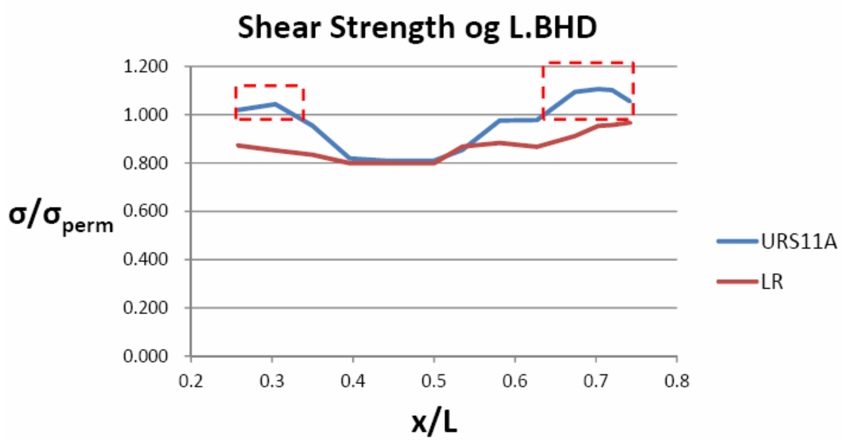
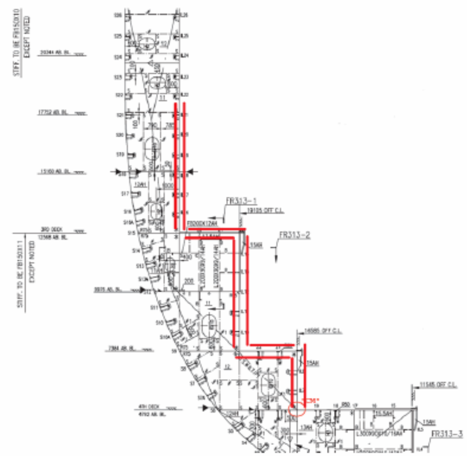


Fig.4.1 Hull Girder Shear Strength at L.BHD



Source: CA report of 9300TEU CV by STX O&S, Korea





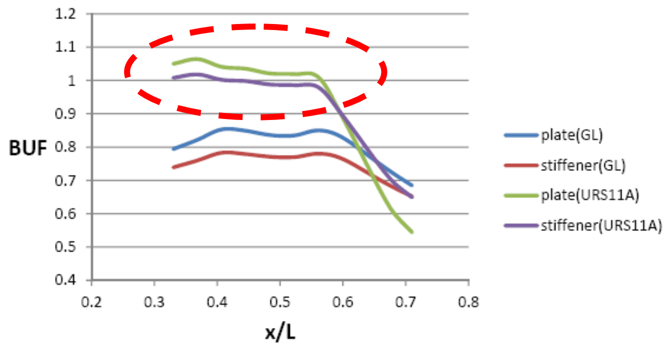
Source: CA report of 13500TEU CV by Hudong-zhonghua

Consequence assessment for UR S11A

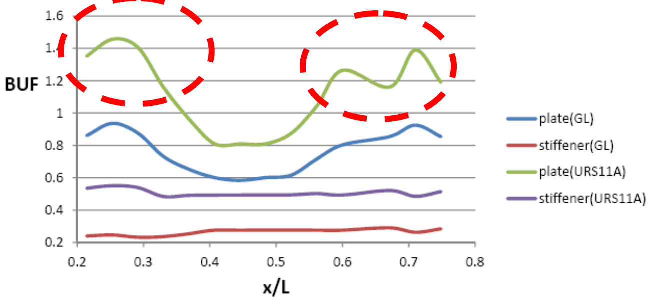
Hull girder strength evaluation

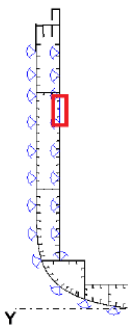
- **The common problems found during CA:**
  - Plate/stiffener **buckling**

Maximum Buckling Utilisation Fator for Double Bottom Girder



Maximum Buckling Utilisation Fator for LBHD_p6





Source: CA report of 20000TEU CV by MARIC

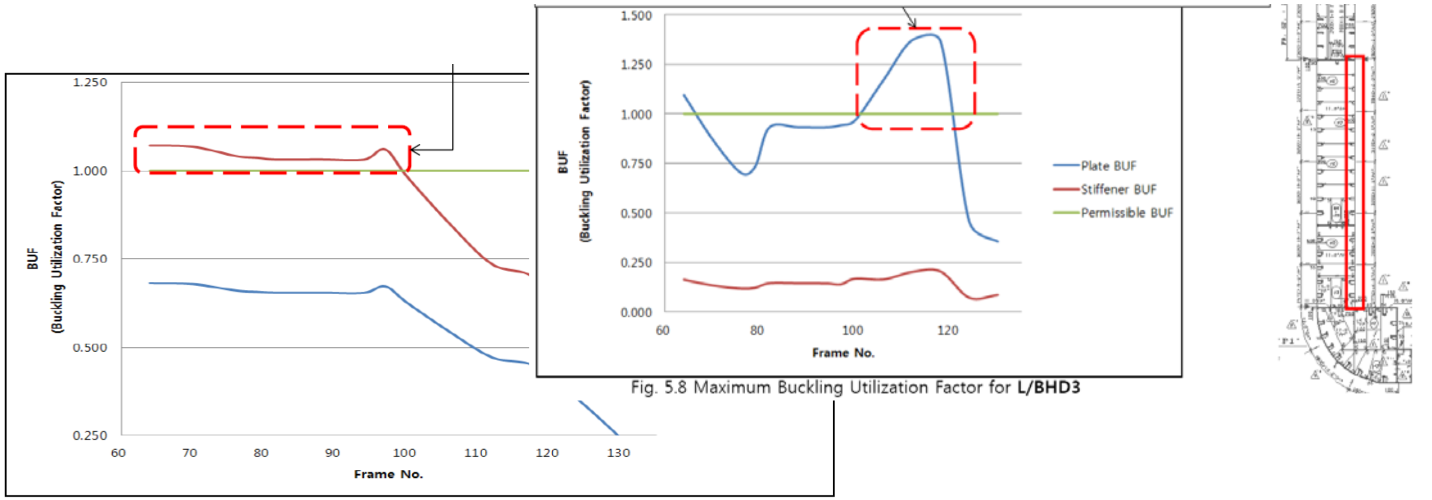
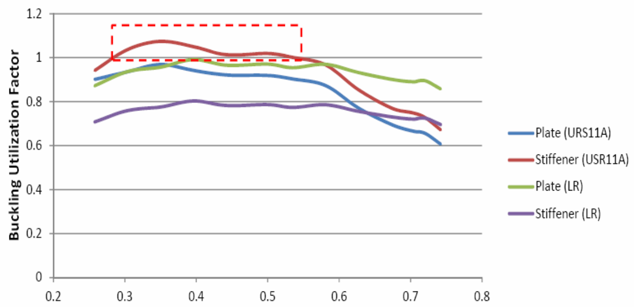


Fig. 5.8 Maximum Buckling Utilization Factor for **L/BHD3**

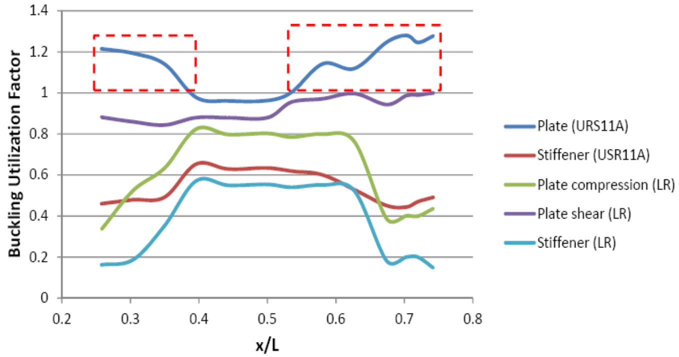
Fig. 5.4 Maximum Buckling Utilization Factor for **NWT D/B Girder**

Source: CA report of 9300TEU CV by STX O&S, Korea

Maximum Buckling Utilization Factor for Double Bottom Girder



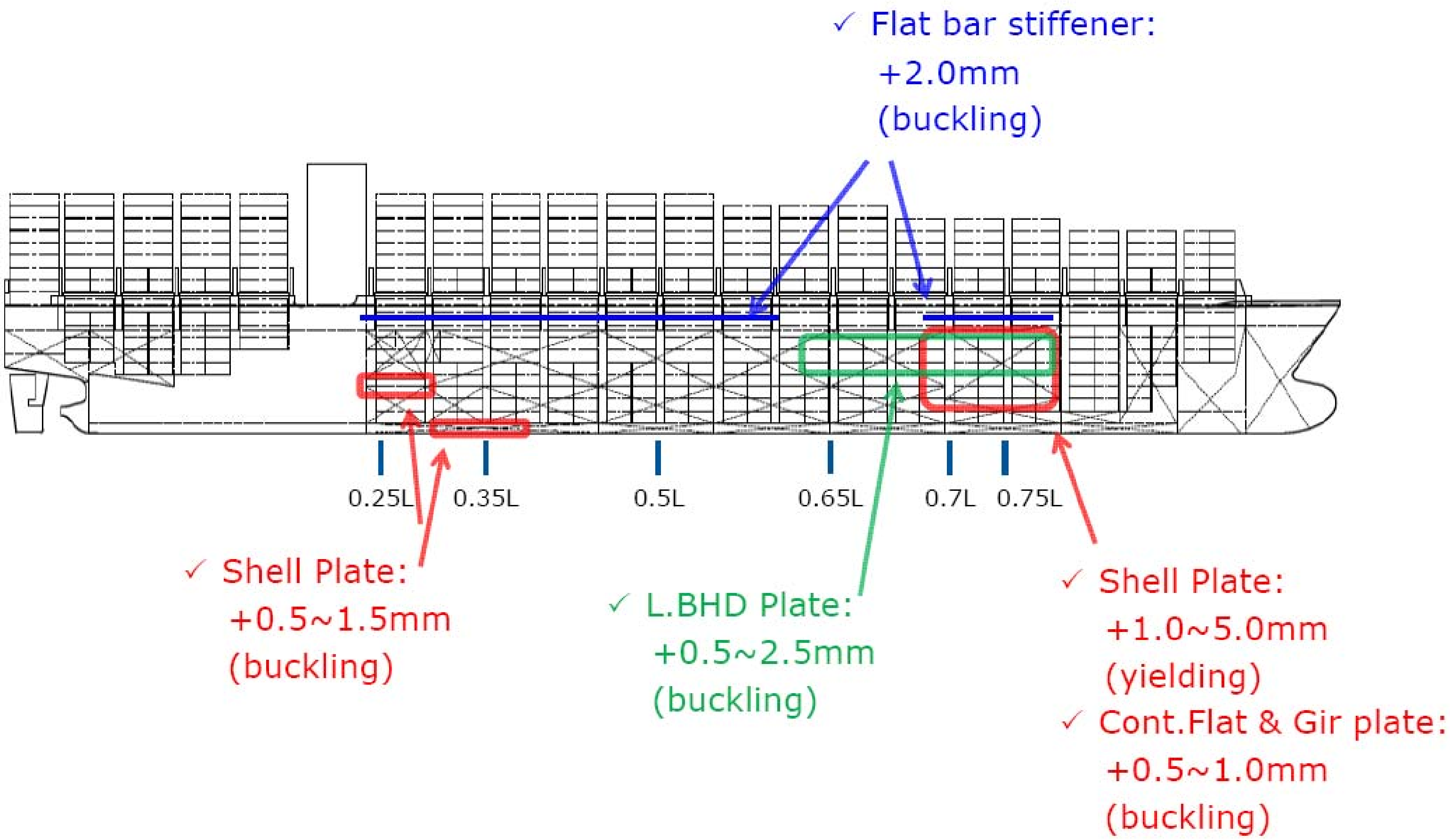
Maximum Buckling Utilization Factor for L. BHD 4



Source: CA report of 13500TEU CV by Hudong-zhonghua

Consequence assessment for UR S11A

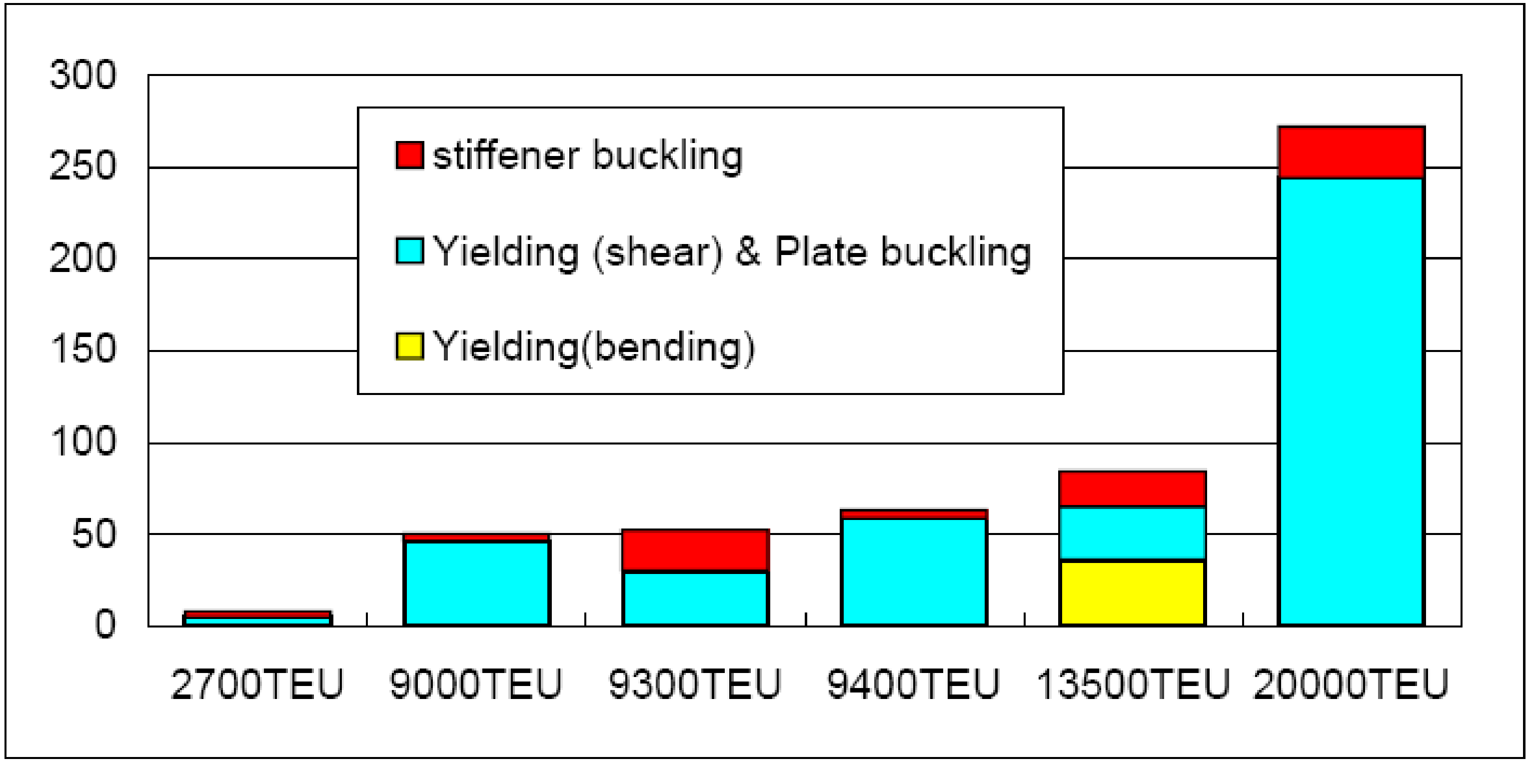
Impact on Hull scantling (only by prescriptive requirement)



Source: CA report of 9000TEU CV by JMU, Japan

Consequence assessment for UR S11A

Impact on Hull scantling (only by prescriptive requirement)



- In the consequence assessment:
  - No impact was found due to ultimate strength (no whipping effect).
  - Only one CV of 13500TEU has problems on hull girder bending strength in the region of 0.3L-0.4L.
  - Plate buckling problems are always due to shear buckling.
  - Hull scantling may be decreased for some areas, but should be evaluated by FE analysis.

Technical issues to be discussed

Consistency for hull girder yielding strength at gross scantling and at net scantlings

- At gross scantlings: $$W_{grs} = \frac{M_{total}}{\sigma_{perm-grs}}$$ (Similar to that in UR S11)
- At net scantlings: $$W_{net} = \frac{CM_{total}}{\sigma_{perm-net}}$$ (Similar to that in CSR or UR S11A)
- If C=1, which means the total vertical bending moments for gross scantlings or net scantlings are the same, e.g. in CSR and UR S11 for oil tankers and bulk carriers. In such case, it would be the same safety level or equivalent criteria for gross scantlings or net scantlings if: $$W_{net}/W_{grs} \approx \sigma_{perm-grs}/\sigma_{perm-net}$$
- In CSR for oil tankers and bulk carriers, the above equation is proved to be true basically. Therefore, it could be deemed that **the safety levels for bending strength between CSR and UR S11 are the same**.
- In UR S11 and UR S11A, the ratio between permissible stress at gross scantlings and at net scantlings is equal to:

$$\sigma_{perm-grs}/\sigma_{perm-net} = \frac{175/k}{\frac{R_{eH}}{\gamma_1\gamma_2}} = \frac{175\cdot\gamma_1\gamma_2}{k\cdot R_{eH}} = \frac{175\cdot k\,\frac{R_{eH}}{235}\cdot 1.24}{k\cdot R_{eH}} = 0.923$$

Technical issues to be discussed

Consistency for hull girder yielding strength at gross scantling and at net scantlings

- But from UR S11A TB document, it could be found that for CVs, the change from gross scantlings to net scantlings gives a change in section moduli of about **3 to 4%** at equivalent deck level (min. section moduli)
- Calculation by *TWG/SWG2* members also find such phenomenon.
- Supposing: $W_{net}/W_{grs} = 0.97$
- Hull girder yielding strength criteria:
  - At gross not less than that at net if: $\frac{0.97}{0.923C} = \frac{1.05}{C} \geq 1$
  - At net not less than that at gross if: $\frac{0.97}{0.923C} = \frac{1.05}{C} \leq 1$
  - If C=1, criteria for hull girder bending strength at gross is larger than that at net.
- **How to deal with such gap for hull girder yielding strength at gross and at net scantlings?**

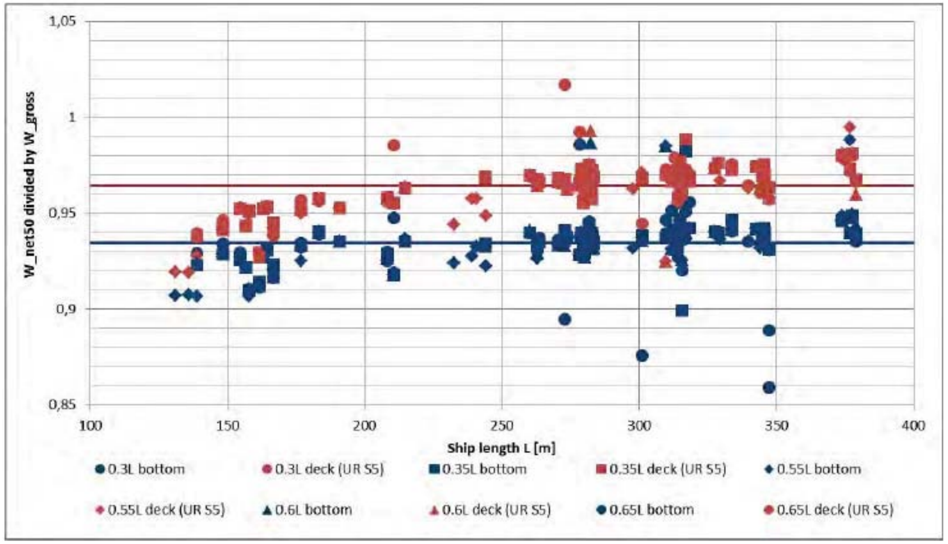


Table 1 Relation between W_{net} and W_{grs} for container ships

Container ships	$W_{net-top}$ (m³)	$W_{grs-top}$ (m³)	$\frac{W_{net-top}}{W_{grs-top}}$
2700TEU	9.780	10.489	0.932
9400TEU	41.594	43.145	0.964
11800TEU	48.036	49.777	0.965
13500TEU	61.343	63.325	0.969
14500TEU	60.188	62.427	0.964
19000TEU	79.418	81.732	0.972
20000TEU	82.254	84.565	0.973
21000TEU	93.758	96.348	0.973

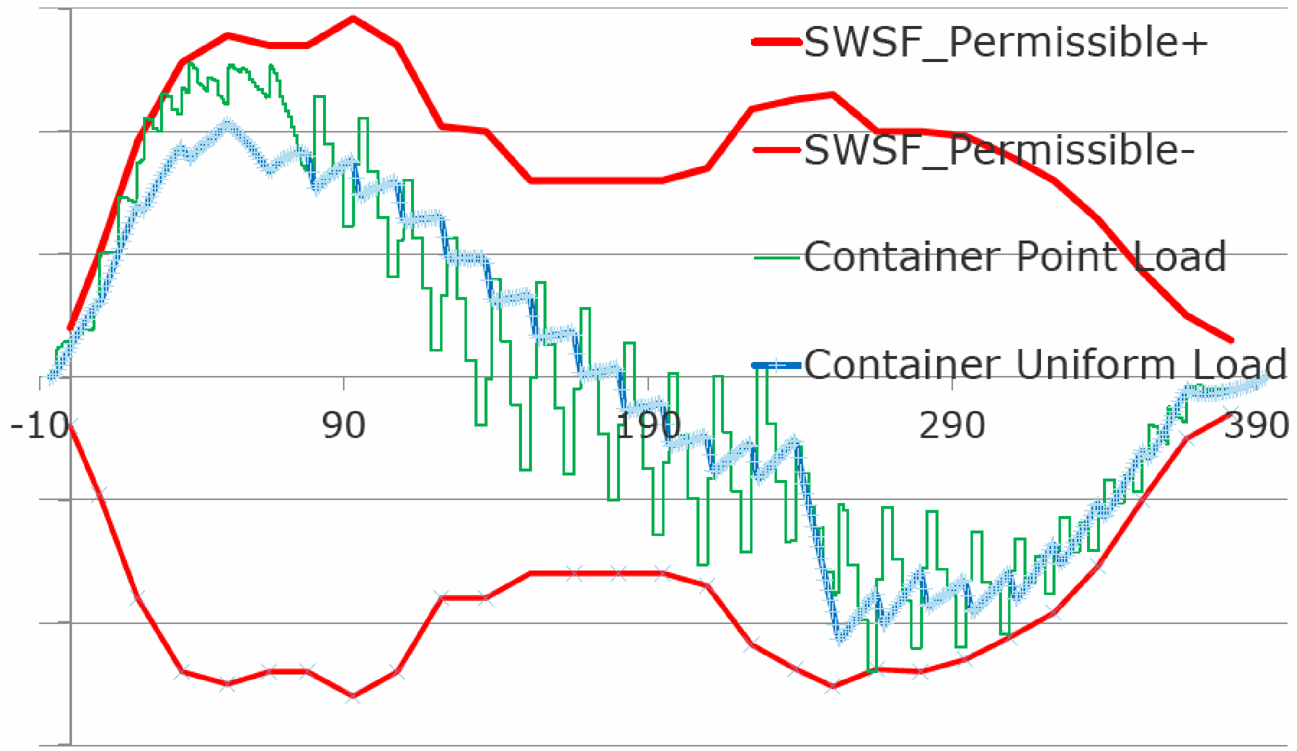
Technical issues to be discussed

Accuracy for SWSF calculation in loading manual and loading computer

- The design SWSF is found to have margin normally and could be optimized to counteract or mitigate the adverse effect by the significant increase of wave shear force. But the hypothesis for optimization is the accuracy for SWSF calculation.
- The accuracy for SWSF calculation depends on:
  - The container weight is accurate.
  - The modeling of container in loading manual and/or loading computer is accurate.
- But unfortunately, the modeling approaches in loading manual and/or loading computer and in FE analysis are totally different.
- Normally, the weight of container is modeled as box or uniform loading in loading manual and/or loading computer.
- But the fact for real ship is the weight of container in hold is directly transferred by container sockets, while **the weight of container on the hatch cover and the weight of hatch cover itself are transferred mostly by the transverse hatch coaming**. Both of such loads are concentrated loads, which will induce the sudden increase of shear force at the location with concentrated loads, same as the approach in global or cargo FE analysis.

Technical issues to be discussed

Accuracy for SWSF calculation in loading manual and/or loading computer



- At the location of transverse BHD (W.T. or supporting BHD), the SWSF will have sudden change by point load modeling approach, which is to be considered seriously when optimizing the SWSF curve.
- The results of SWSF by point load modeling approach are from global FE analysis, while those from NAPA system are being carried out for further investigation.

Possible further plans for TWG/SWG2

- Carry out further study and discussion on the accurate modeling of SWSF in loading manual and/or loading computer, consistent with the real distribution in global FE analysis.

- Exchange of information and views on hull girder ultimate strength considering whipping effect by IACS project team and/or relevant Classification Societies and/or other association and/or JIP project.

- Carry out calibration of PSF for container ships by means of Structural Reliability Analysis (SRA).

Summary

- ***IACS*** has noticed the main concerns about new URs on container ship, and agreed to continue with their efforts to expand technical requirements for container ship strength and deal with shipbuilders' concerns in order of priority, including **hull girder ultimate strength**, **whipping** etc.
- **UR S11A** and **UR S34** have been uniformly implemented by ***IACS Societies*** for container ships contracted for construction on or after **1 July 2016**.
- It could be found from ***ASEF*** consequence assessment that only prescriptive requirement by **UR S11A** has little impact (mainly due to hull girder shear strength and buckling strength) on hull scantlings, but:
  - For future design of container vessels, min. SWBM normally set to positive **with the value equal to minimum hogging SWBM**.
  - When carrying out optimization, accuracy of SWSF calculation is to be seriously considered.
- There is still some technical issues to be further studied or discussed. Exchange of information and views on hull girder ultimate strength considering whipping effect would be the main task for ***TWG/SWG2*** next year.

Active Shipbuilding Experts' Federation

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Thank you for your attention.

ASEF/TWG/SWG2