Farhad Ahmed

6th EMship cycle: October 2015 – February 2017

Master Thesis

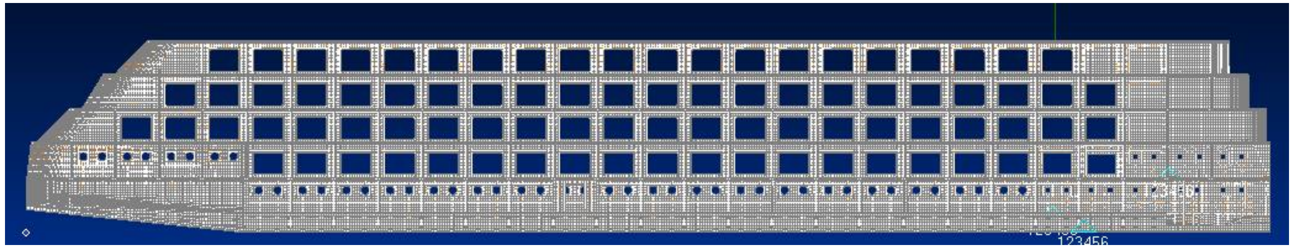
Development of guidelines allowing to predict the contribution of the superstructure to the hull girder strength

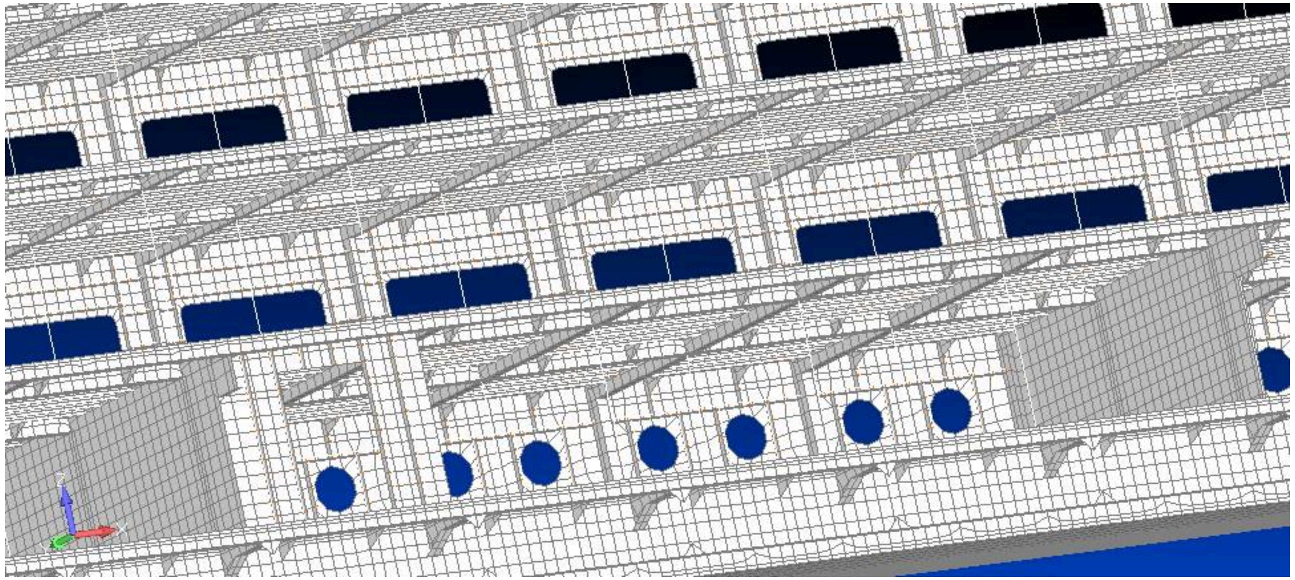
Supervisor: Professor Dr. Maciej Taczala, West Pomeranian University of Technology , Szczecin, Poland
Ing. Wa Nzengu Nzengu, Bureau Veritas, Antwerp, Belgium
Reviewer: Professor Dr. Philippe Rigo, University of Liège, Liège, Belgium

Szczecin, February 2017

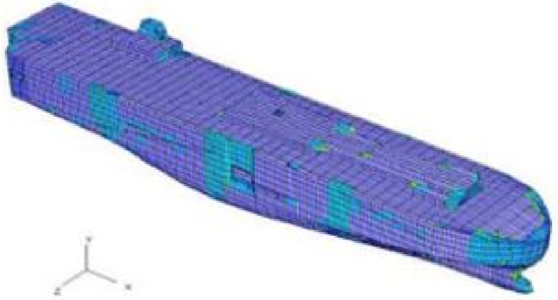
Content

- Introduction
- State of Art
- Scope of Improvement
- Investigation
- Proposal of New Formula
- Application
- Conclusion

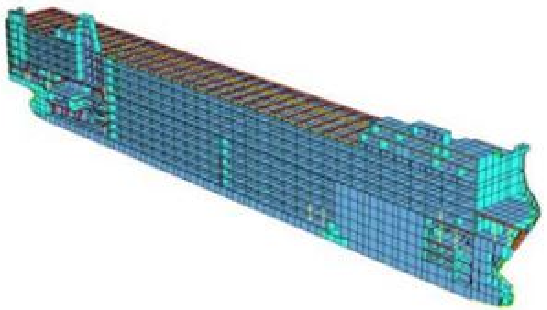




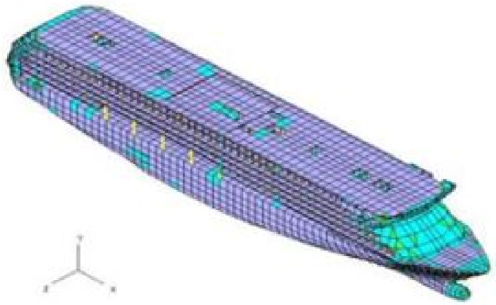
Introduction



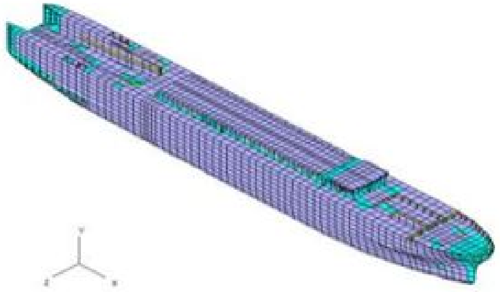
Car Carrier: Closed superstructure without opening or side ramp



Live Stock Carrier: Open structure on pillar arrangement, high reduction of shear stiffness of superstructure sides



Cruise Ships: Large openings in superstructure sides, internal empty spaces



Tank Car Carrier: Very long superstructure on the very flexible upper deck

Different types of vessels with different types of superstructure (*Vedran Zanic, 2016)*

Introduction

Focus

✓ Passenger Vessel

Contribution of superstructure to hull girder strength

✓ Longitudinal stress transfer between hull girder and superstructure

✓ Sharing of longitudinal strength between hull girder and superstructure

Introduction

Factors affecting hull superstructure interaction phenomena:

- ✓ Bending stiffness of hull and superstructure
- ✓ Foundation stiffness of deck
- ✓ Shear stiffness of hull and superstructure sides
- ✓ Length and breadth of the superstructure compared to the length and breadth of hull girder
- ✓ Connections between hull and superstructure i.e. bulkheads, pillar lines, etc.
- ✓ Yield strength and thickness of the plates and other structural elements.
- ✓ Vertical and longitudinal continuity of the longitudinal bulkheads
- ✓ Use of pillars or large window bays, etc.

Introduction

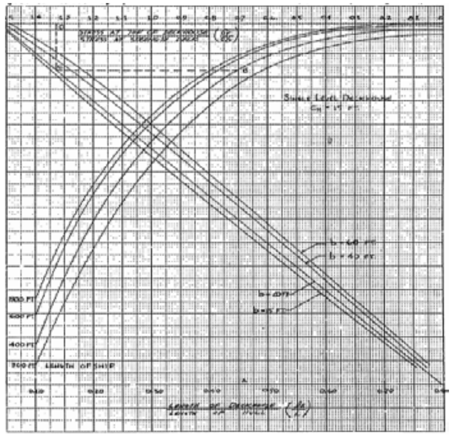
Challenges:

- ✓ Scientific: Generalize all factors to form any simple analytic formula, due to wide range of structural diversity and complex interactions between all structural members
- ✓ Economic/Industrial: Direct calculation (FEA) is very costly and time consuming, specially for small vessels

State of Art

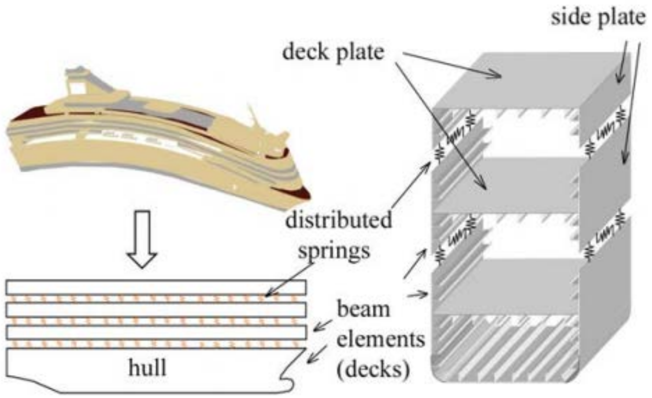
Plane Stress Theory:
Joseph T. Kammerer (1966)

- ✓ Analytical method based on semi-empirical results of full scale experiments



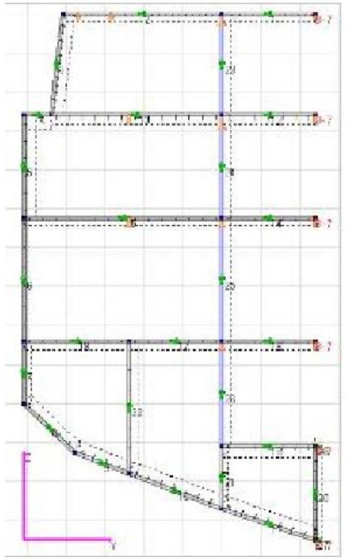
Coupled Beam Method:
Hendrik Naar, (2006)

- ✓ Each deck considered as a thin-walled beam



Kirchhoff's Method:
LBR5 (Prof. Philippe Rigo, ULg)

- ✓ Bending Strip Theory
- ✓ Weight Optimization



State of Art

BV Rules: (Pt B, Ch 4, Sec 2)

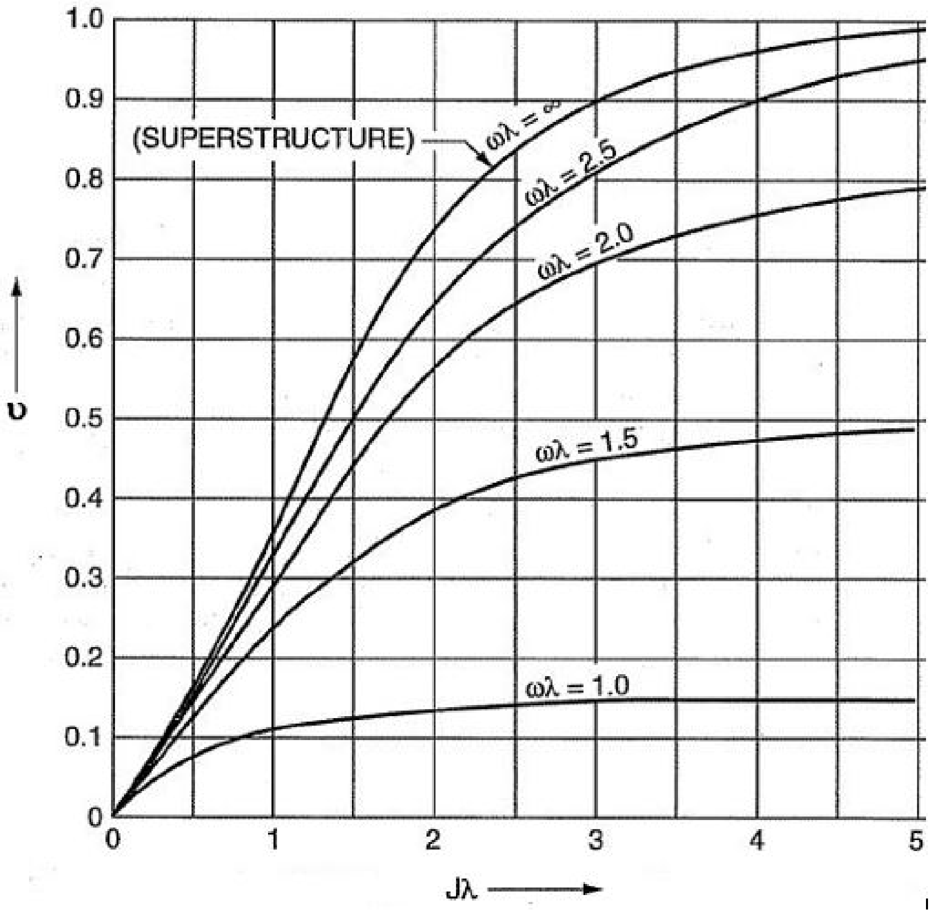
Bending Efficiency, $\nu = \sigma_1' / \sigma_1$

$\nu_i = \nu_{i-1}(0.37\,\chi - 0.034\,\chi^2)$

$\chi = 100\, j\, \lambda \le 5$

$$j = \sqrt{\frac{1}{\frac{1}{A_{SH1}} + \frac{1}{A_{SHe}}} \cdot \frac{\Omega}{2.6}}$$

$$\Omega = \frac{(A_1 + A_e)(I_1 + I_e) + A_1 A_e (e_1 + e_e)^2}{(A_1 + A_e) I_1 I_e + A_1 A_e (I_1 e_e^2 + I_e e_1^2)}$$

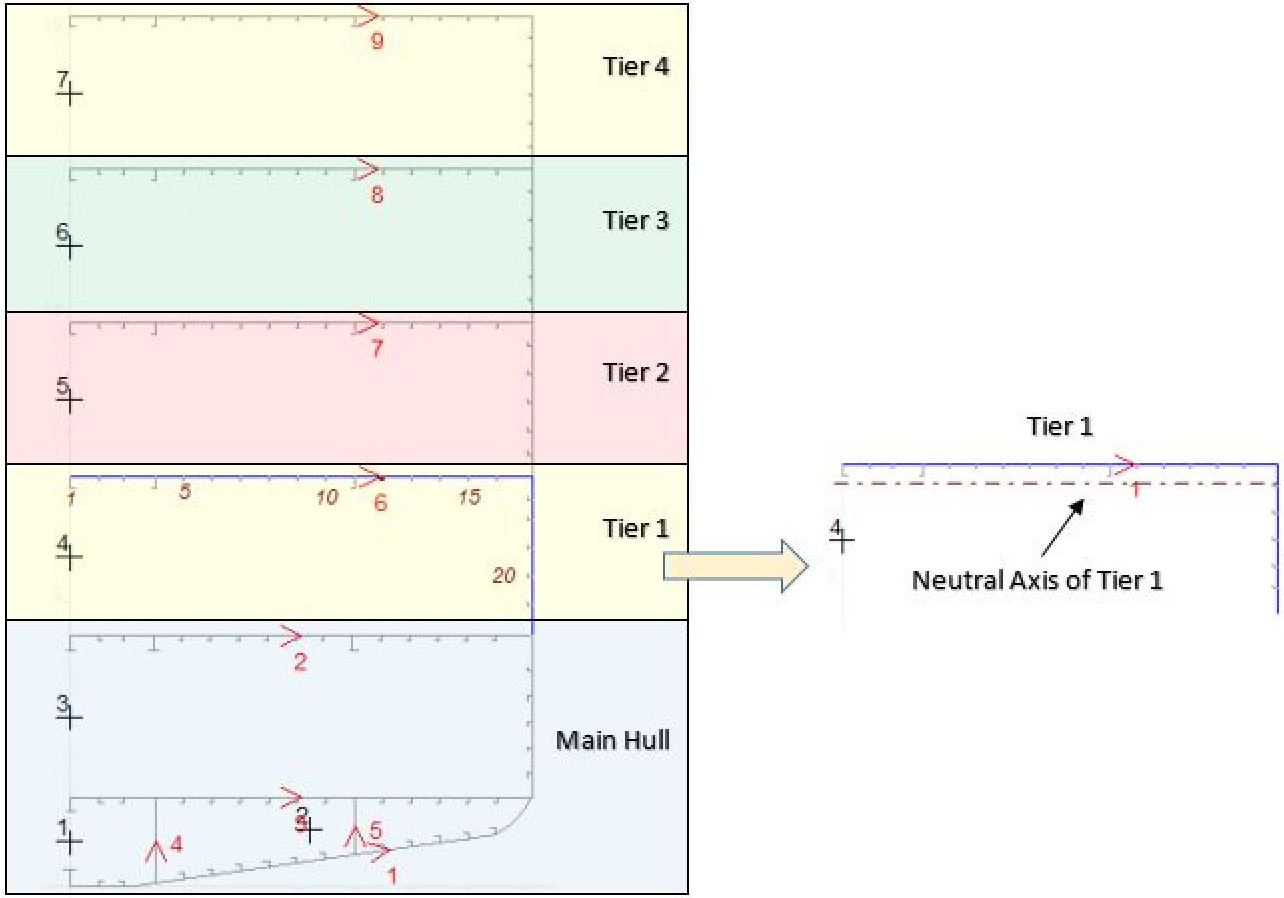


H.A. Schade, 1966

State of Art

Rule formula is tier by tier:

- ✓ Each tier has different bending efficiency, but elements from same tier has same bending efficiency
- ✓ Bending efficiency of any tier is calculated in NA of that tier, considering the tier acts as a single beam



Scope of Improvement

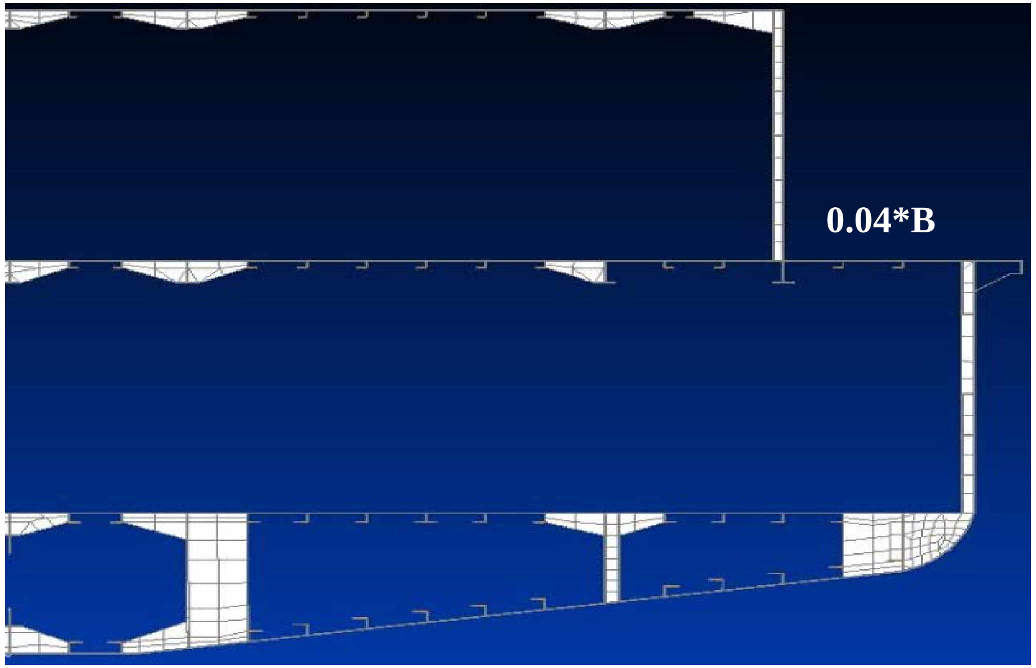
Factors considered in Rule methodology:

- ✓ Superstructure length
- ✓ Cross-section area of hull & superstructure
- ✓ Section moments of inertia of hull & superstructure
- ✓ Vertical shear areas
- ✓ Vertical & lateral shear lag, etc.

Scope of Improvement

Rule method is applicable for:

- ✓ Superstructure side plating not being inboard of the shell plating more than 0.04B (Pt B, Ch 1, Sec 2)
- ✓ Midship i.e. away from superstructure end



Scope of Improvement

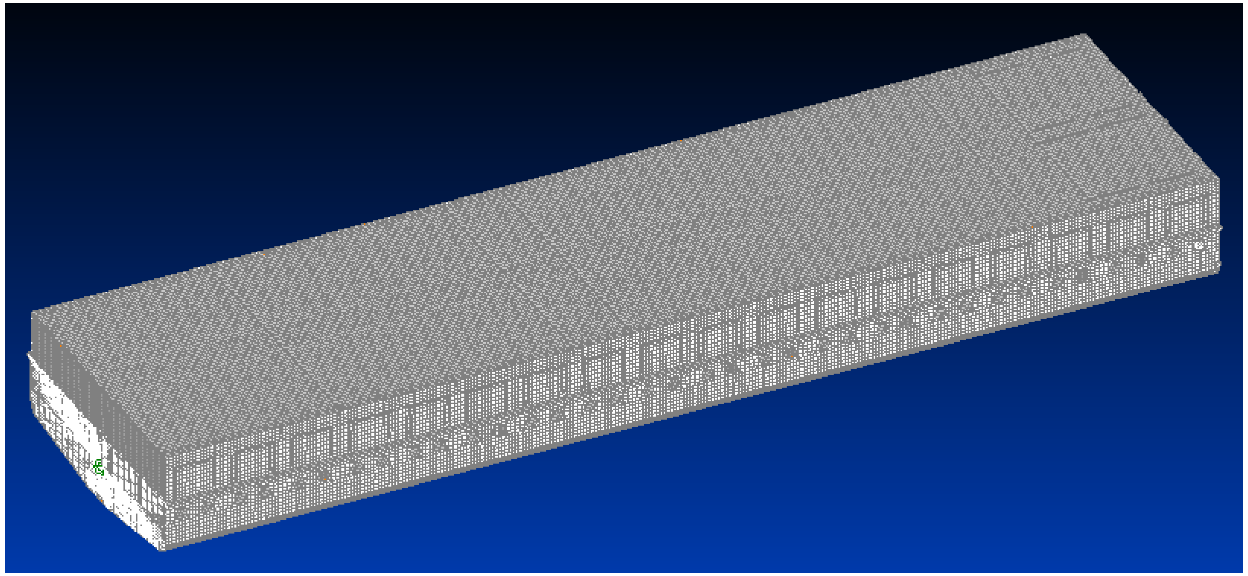
Rule method does not consider:

- ✓Ratio of superstructure length to hull length (r_{L})
- ✓Ratio of superstructure deck openings to total deck area (r_D)
- ✓Ratio of superstructure side openings to total lateral area (r_S)
- ✓Location of side openings, etc.

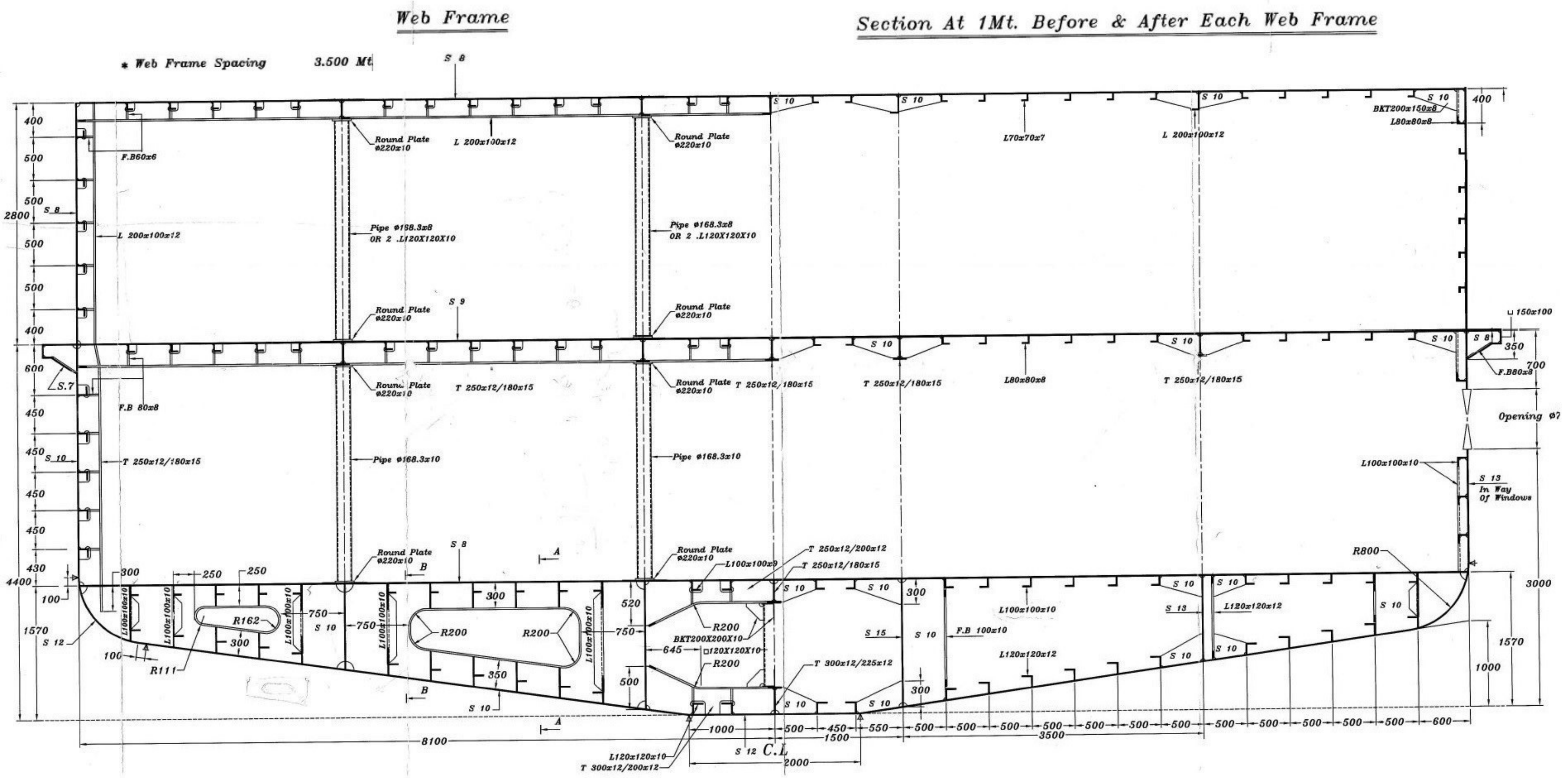
Investigation

A standard study model:

- ✓ Two superimposed box girders
  - FEM (Femap)
  - Length: 63m
  - r_L = 1.00, r_S = 0, r_D = 0
- ✓ Different modified models – different parameters



Investigation



Midship Section of Standard Study Model

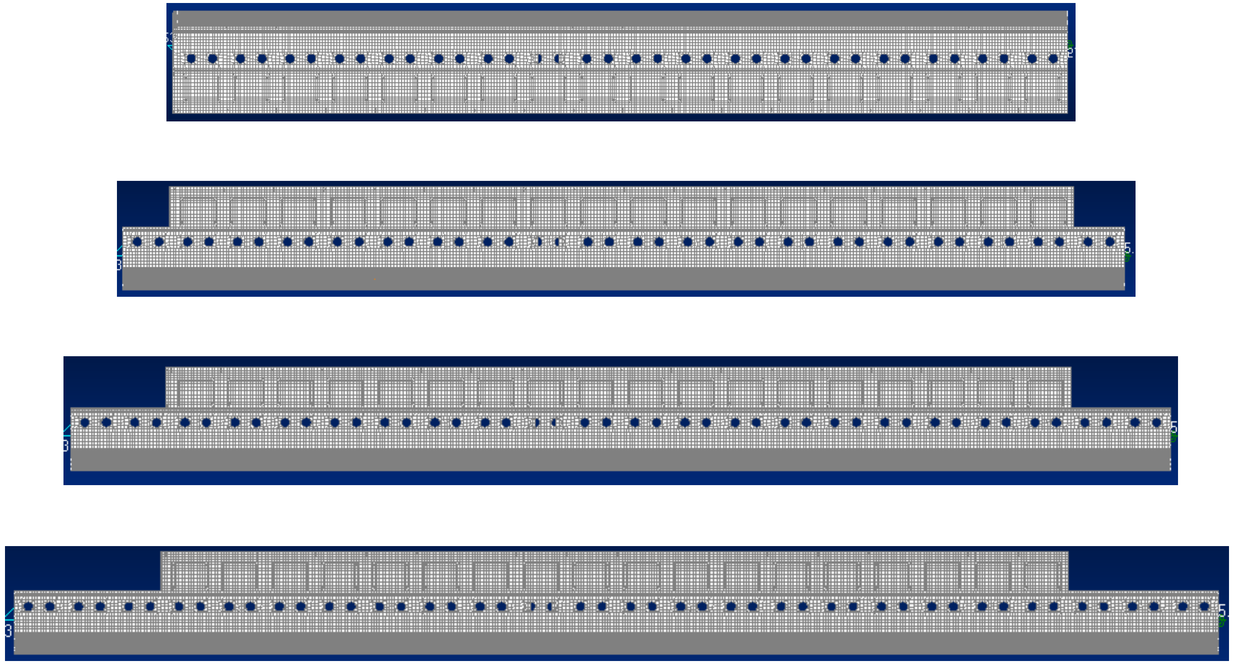
Investigation

Ratio of superstructure length to hull length (r_L)

✓ Modified models with various hull lengths

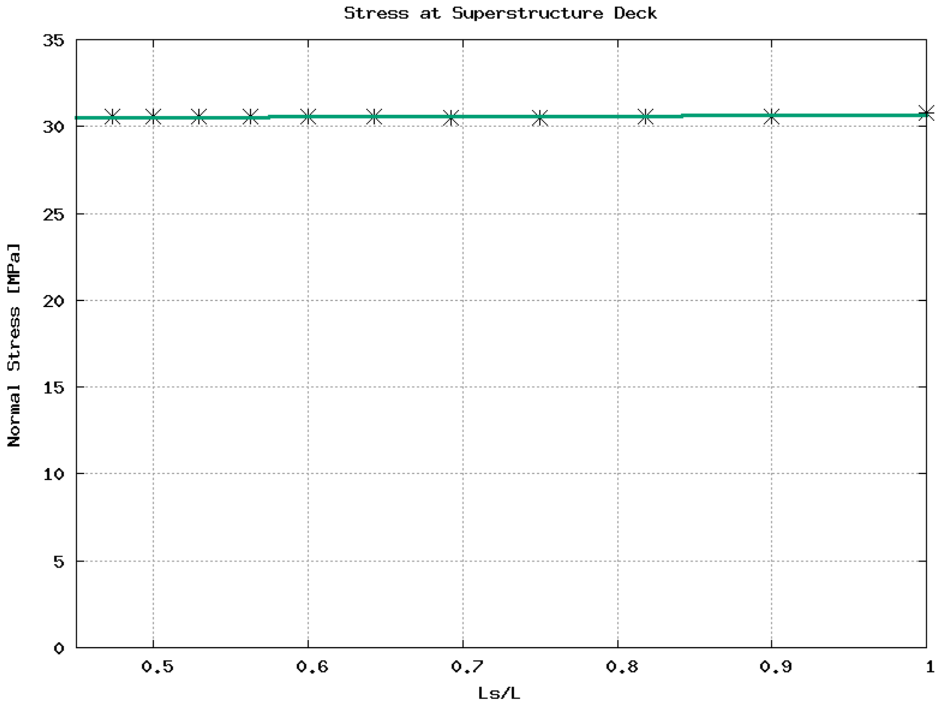
✓ Same length of superstructure for all cases

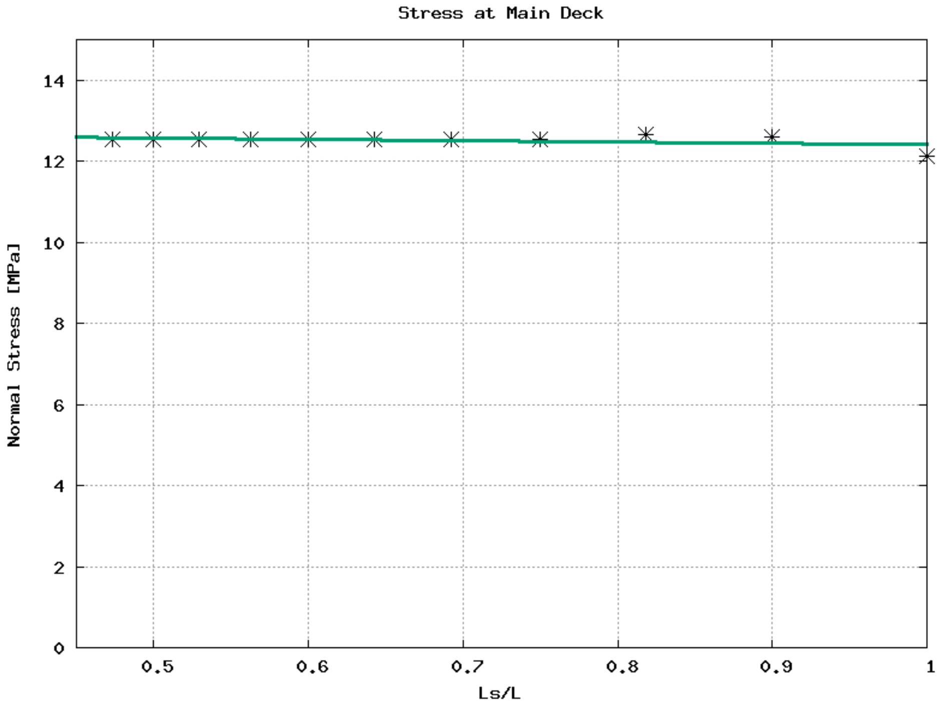
✓ Only hull length was modified



Investigated range of $r_L : 1.00 \sim 0.47$

Investigation

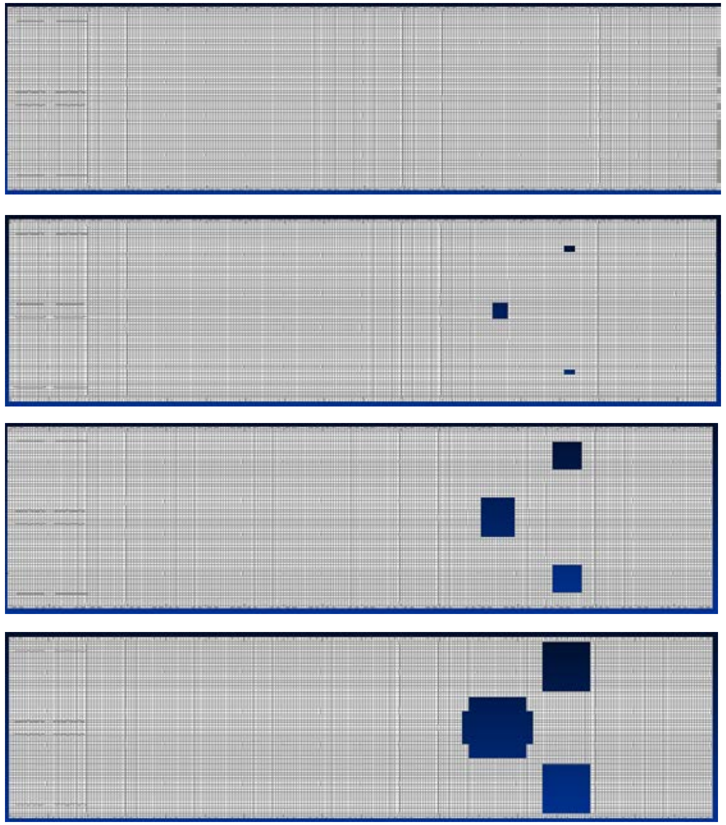




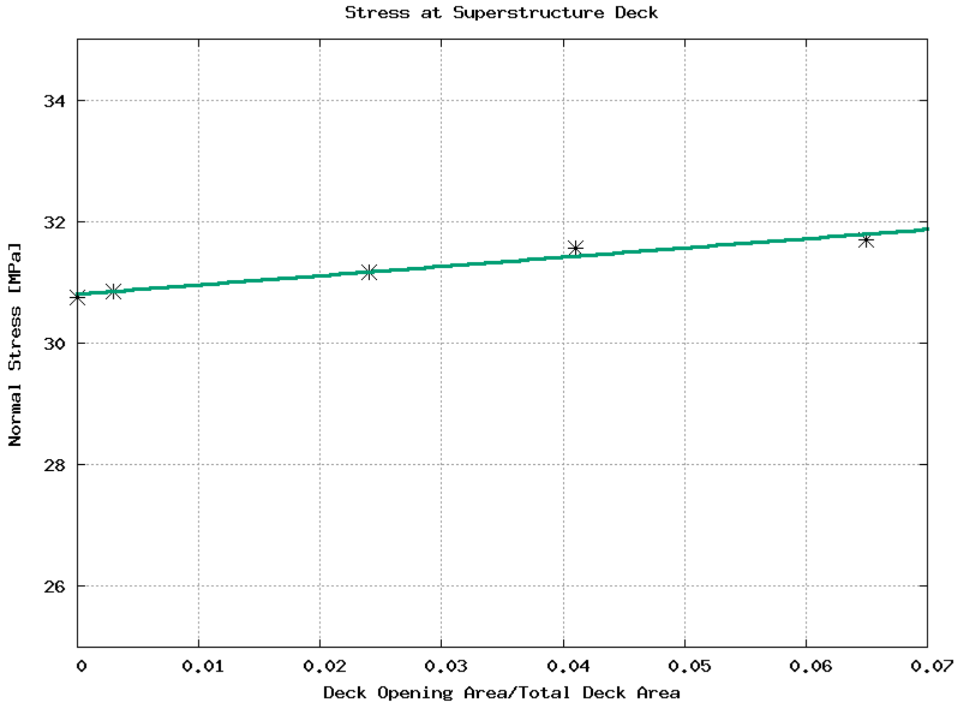
Investigation

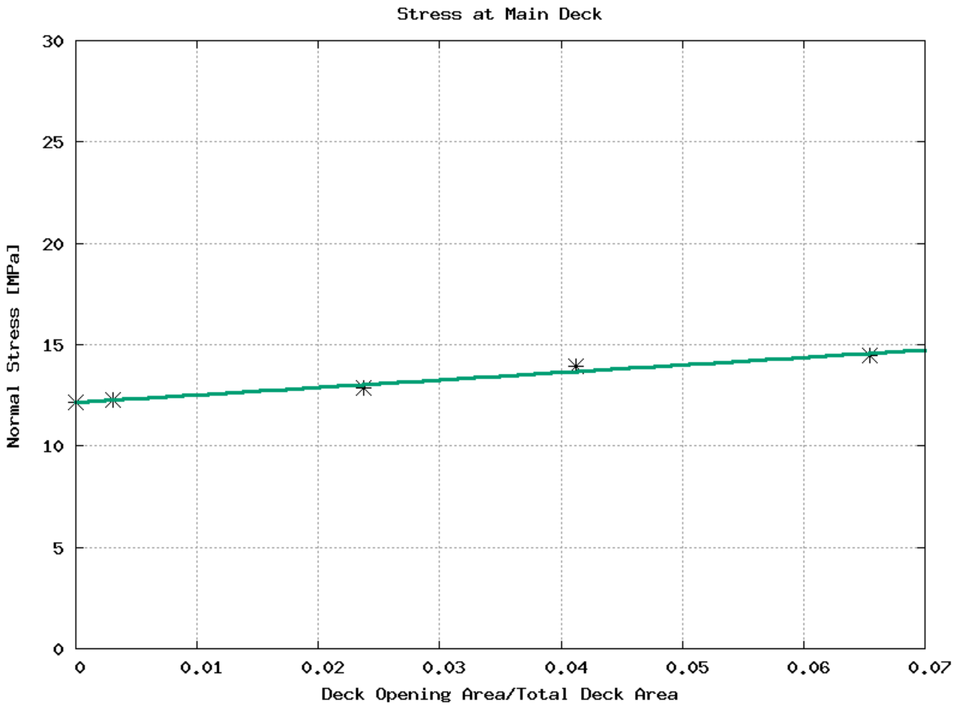
Ratio of superstructure deck openings to total deck area (r_{D})

- ✓ Modified models with various deck opening sizes
- ✓ Only deck opening size was modified



Investigation

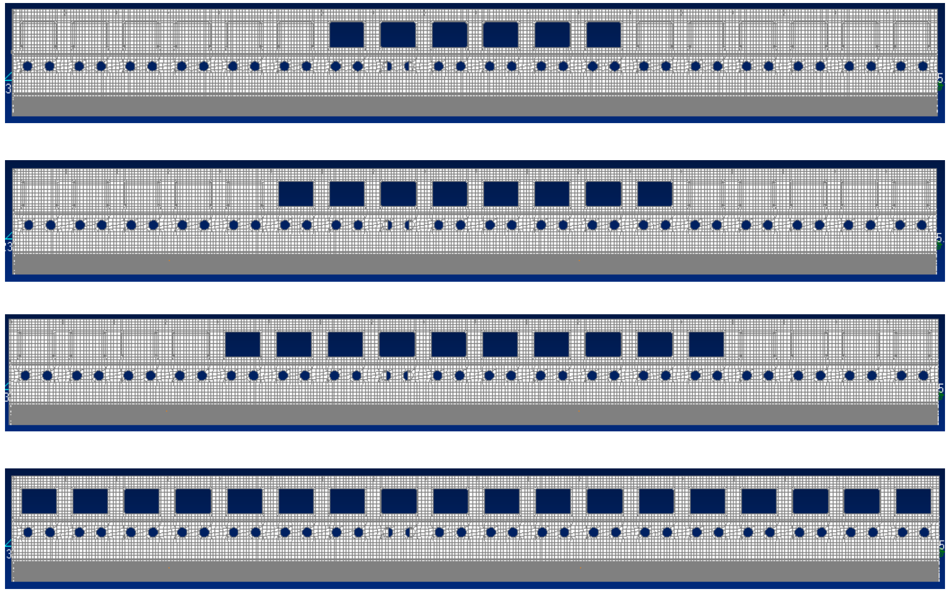




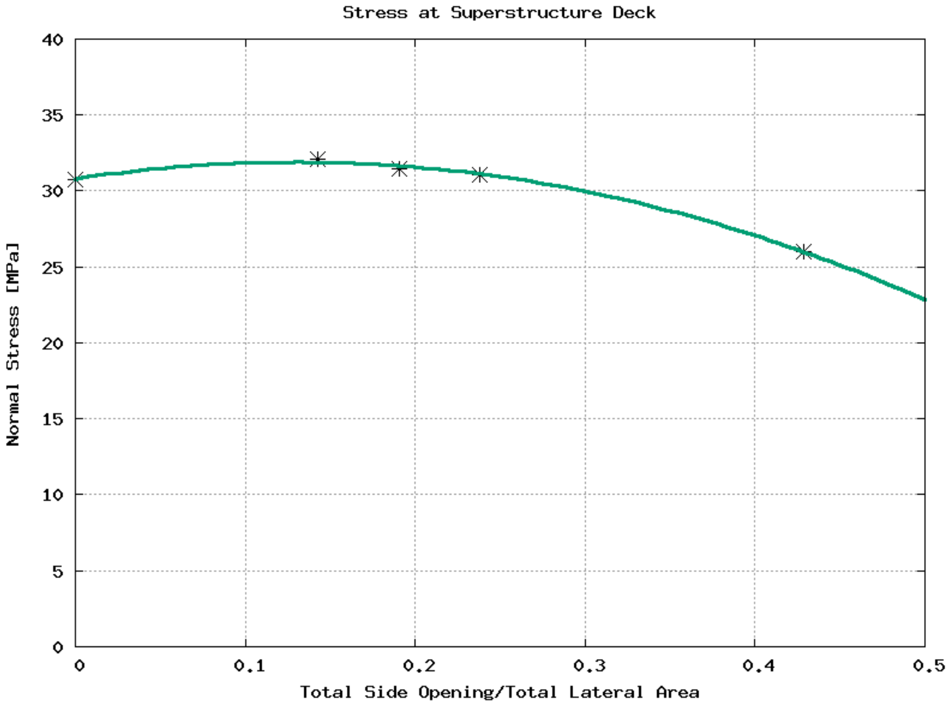
Investigation

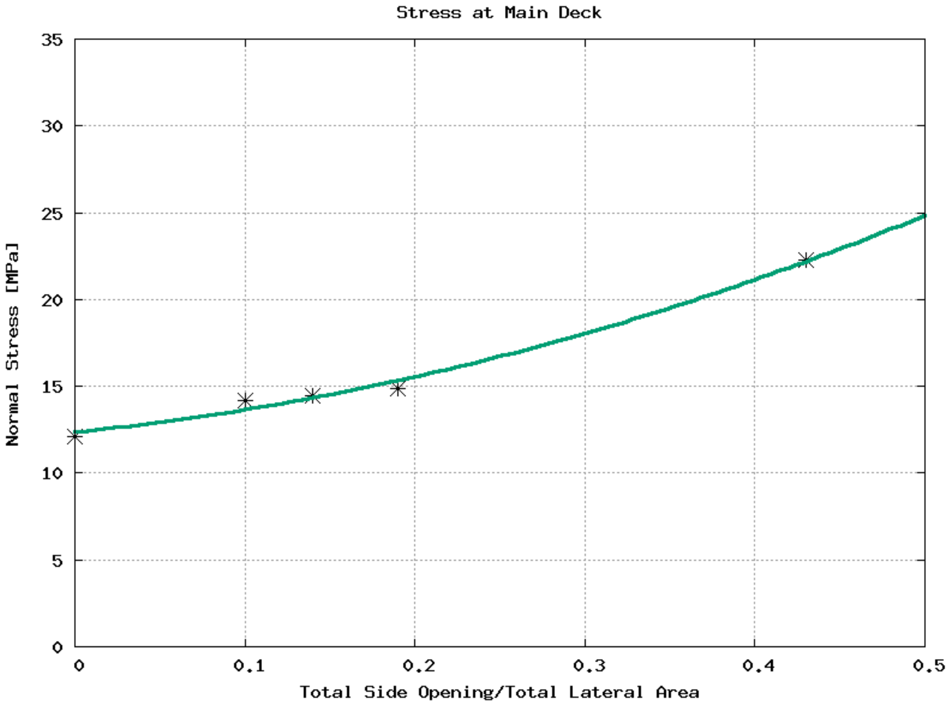
Ratio of superstructure side openings to total lateral area (r_S)

- ✓ Modified models with various side openings
- ✓ Only side opening area was modified



Investigation





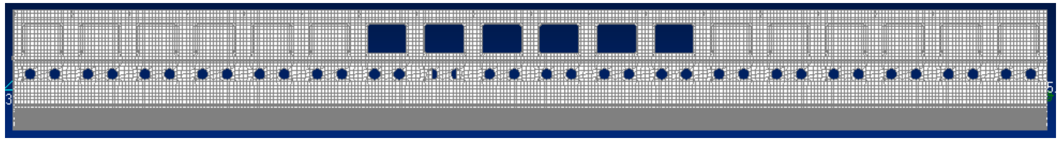
Investigation

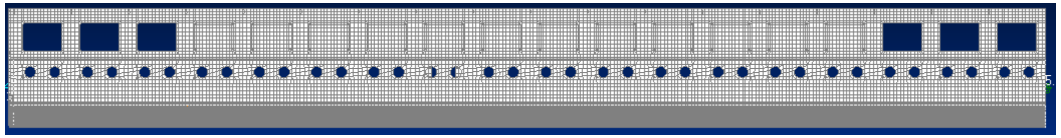
Location of superstructure side openings

✓Same side opening area

✓Different locations of side openings

- midship
- fore and aft

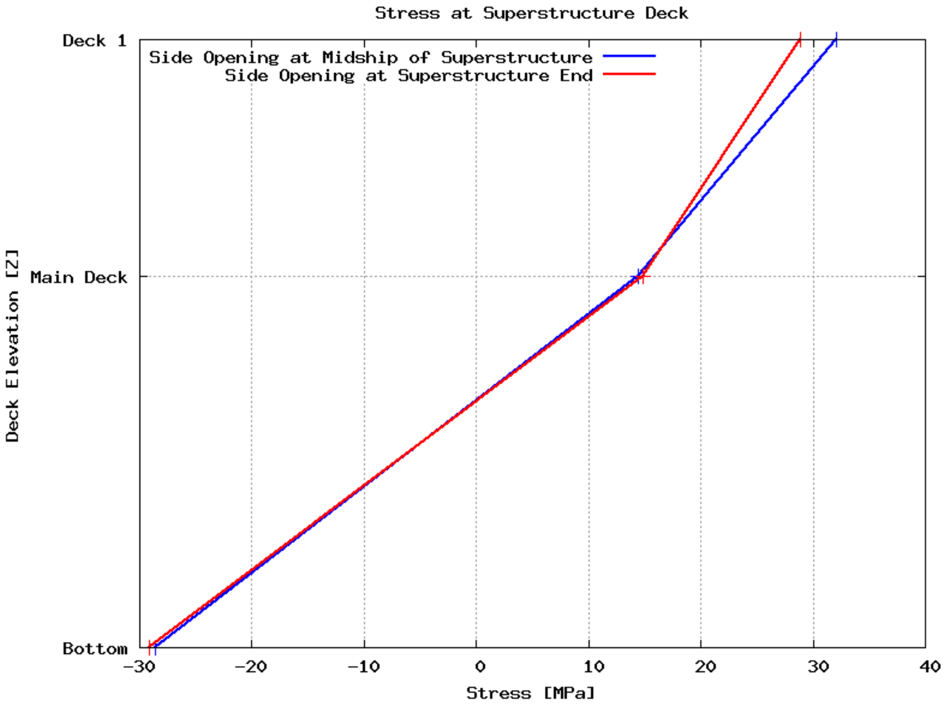




Investigation

Location of superstructure side openings

- ✓Longitudinal stress is higher at superstructure when side openings are located at midship
- ✓The difference is stress is around 10% in this case



Proposal of New Formula

Integration of r_S:

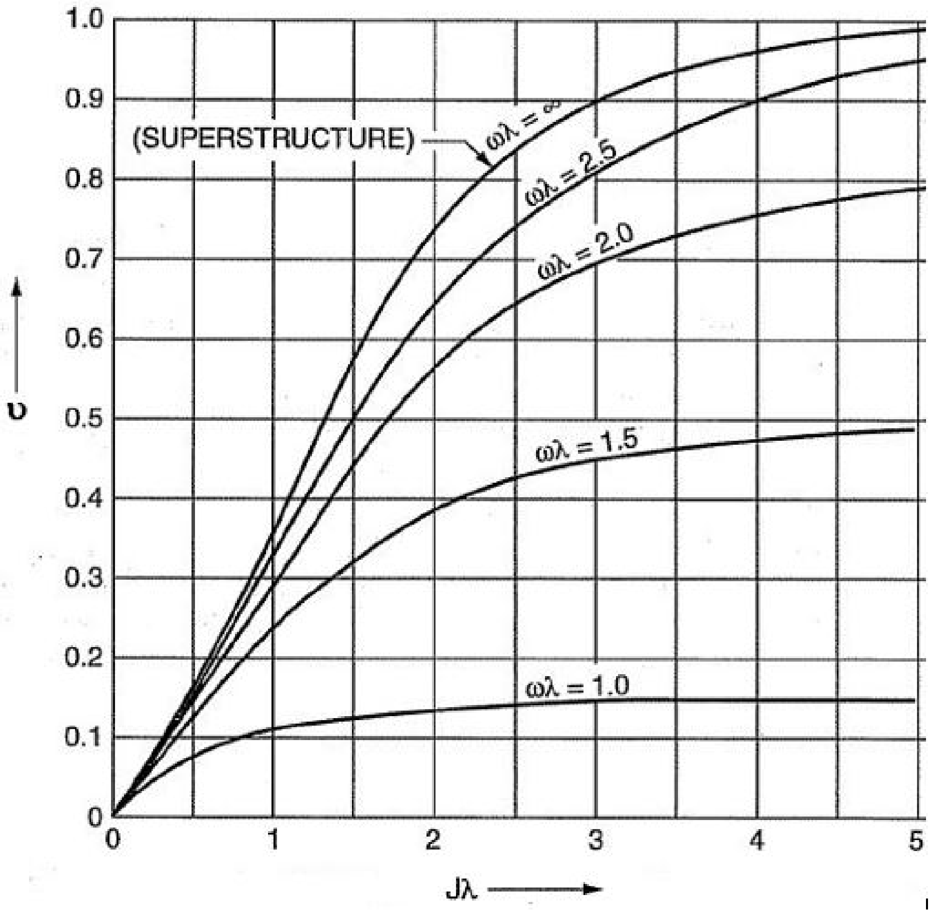
$v_i = v_{i-1}(0.37\,\chi - 0.034\,\chi^2)$

$\chi = 100\,j\,\lambda \leq 5$

$v_i = v_{i-1}(0.37\,\chi_{new} - 0.034\,\chi_{new}^2)$

$\chi_{new} = \chi * k_{rs}$

$k_{rs} = f(r_S)$



H.A. Schade, 1966

Proposal of New Formula

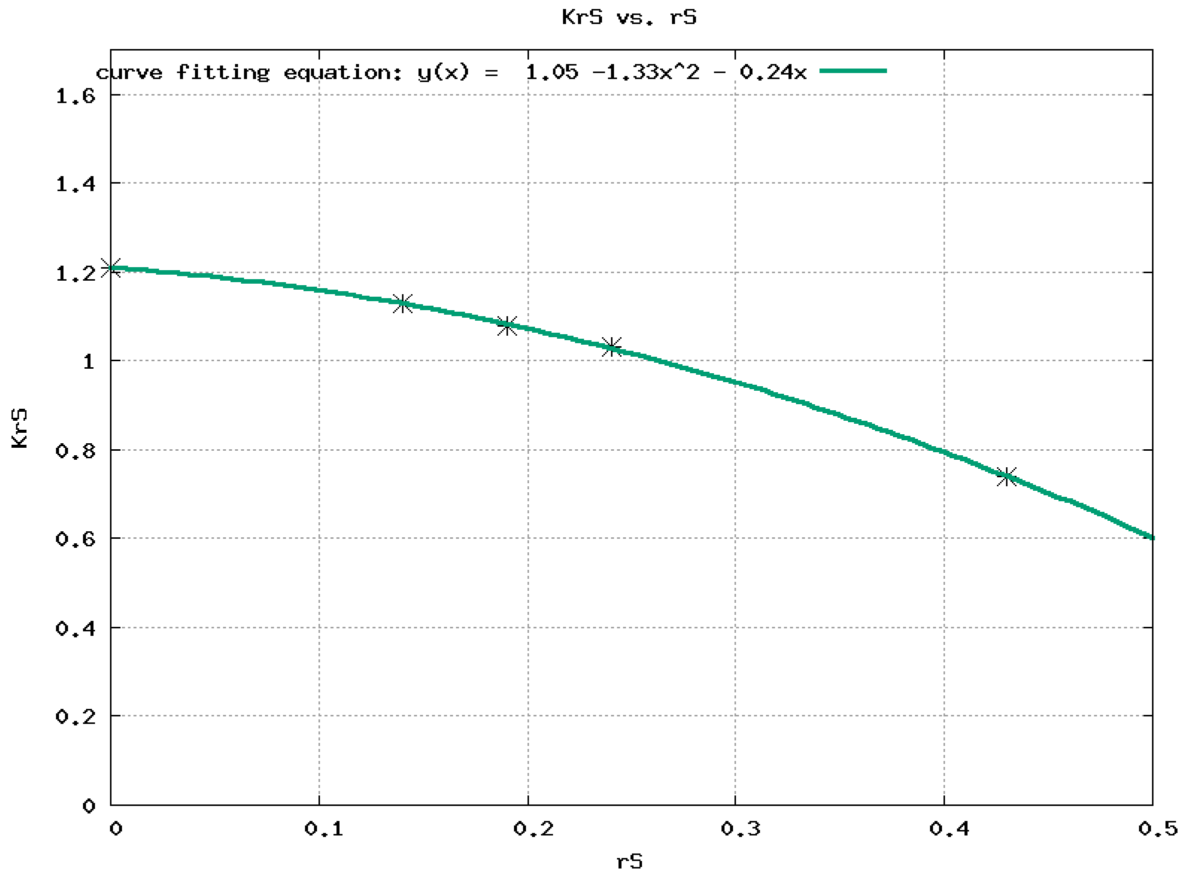
Integration of r_S:

$$k_{rs} = \frac{\chi_{new}}{\chi}$$

FEA Bending Efficiency (χ_{new})

Rule Bending Efficiency (χ)

$$k_{rs} = 1.05 - 1.33\, r_S^2 - 0.24\, r_S$$



Effect of r_S *on* k_{rs}

Proposal of New Formula

Integration of r_S:

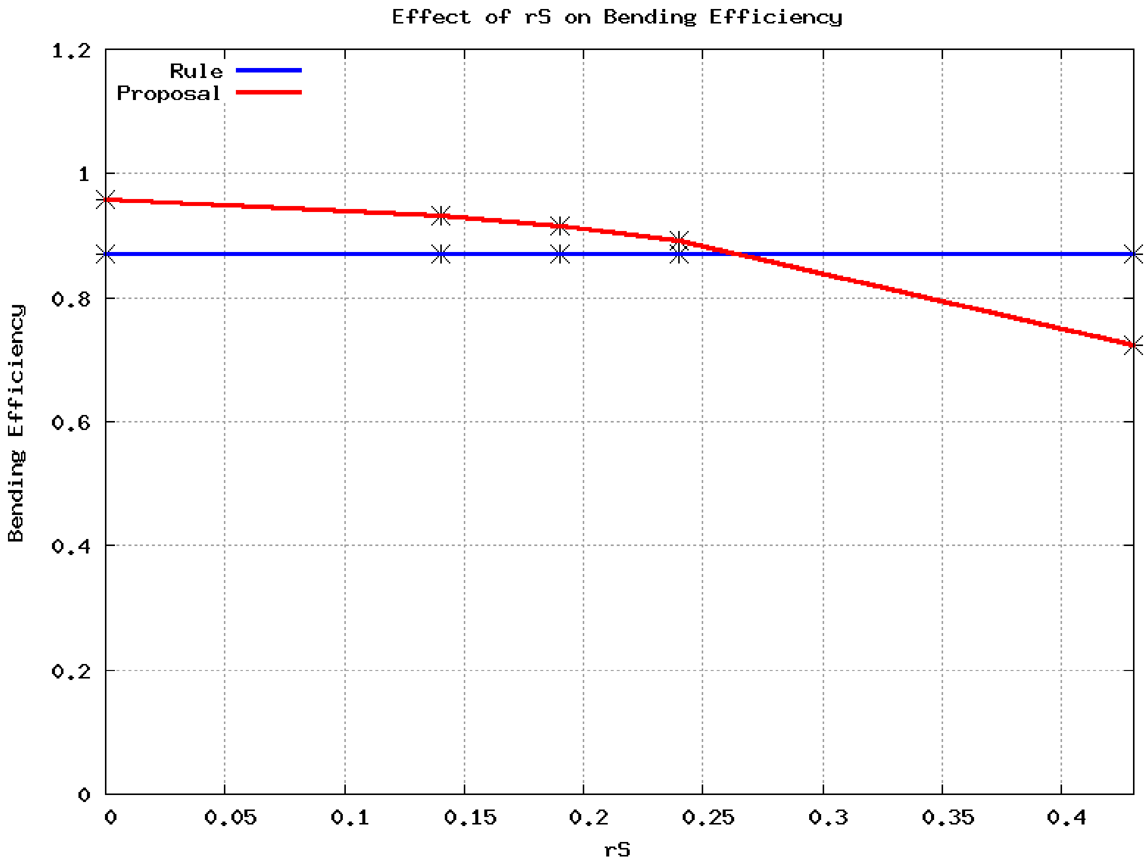
$$\nu_i = \nu_{i-1}(0.37\,\chi_{new} - 0.034\,\chi_{new}^2)$$

$$\chi_{new} = 100\;k_{rs}\,j\,\lambda \leq 5$$

$$k_{rs} = 1.05 - 1.33\,r_S^2 - 0.24\,r_S$$

$$j = \sqrt{\frac{1}{\frac{1}{A_{SH1}} + \frac{1}{A_{SHe}}} \cdot \frac{\Omega}{2.6}}$$

$$\Omega = \frac{(A_1 + A_e)(I_1 + I_e) + A_1 A_e (e_1 + e_e)^2}{(A_1 + A_e) I_1 I_e + A_1 A_e (I_1 e_e^2 + I_e e_1^2)}$$



Effect of r_S on Bending Efficiency

Proposal of New Formula

Validation:

- ✓ FE model of a complete ship
- ✓ The vessel complies with NR217
- ✓ Passenger vessel:

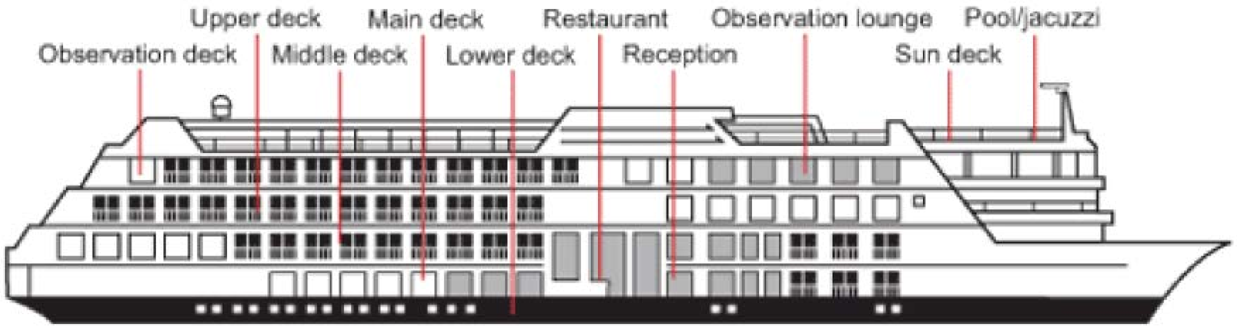
  Length – 112m

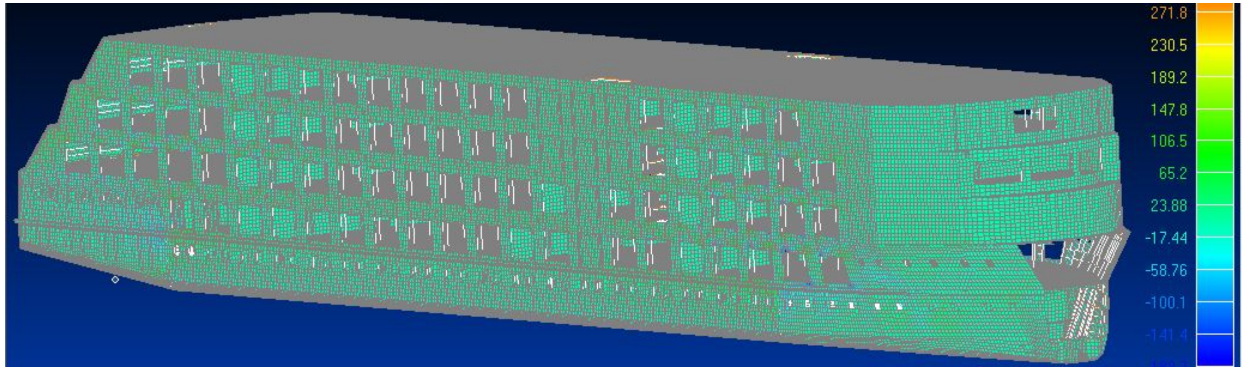
  Breadth – 16.2m

  Draught – 2.2m

  Gross Tonnage – 2096

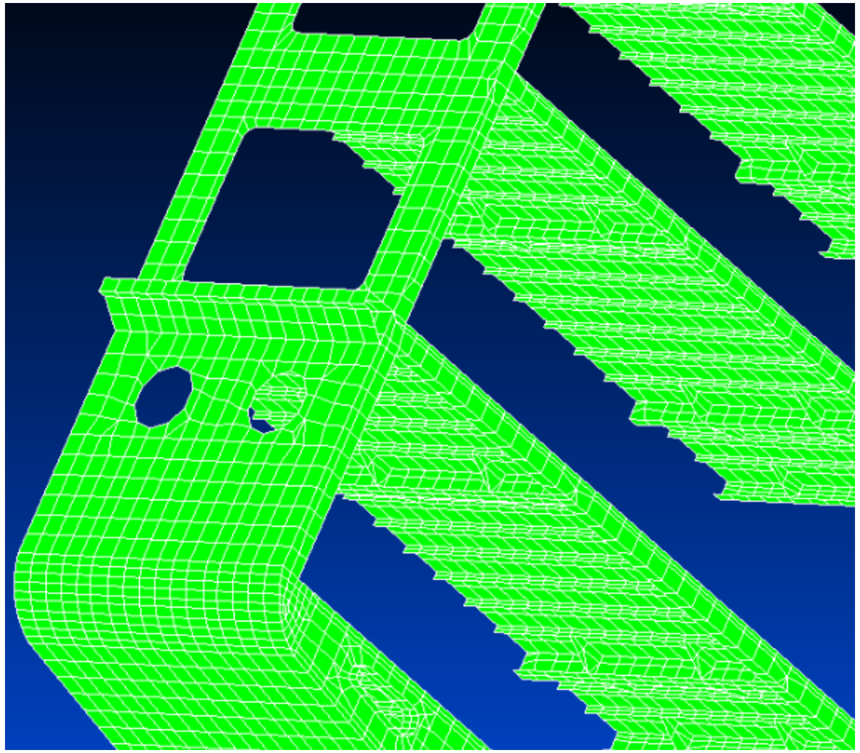
  Material – Steel

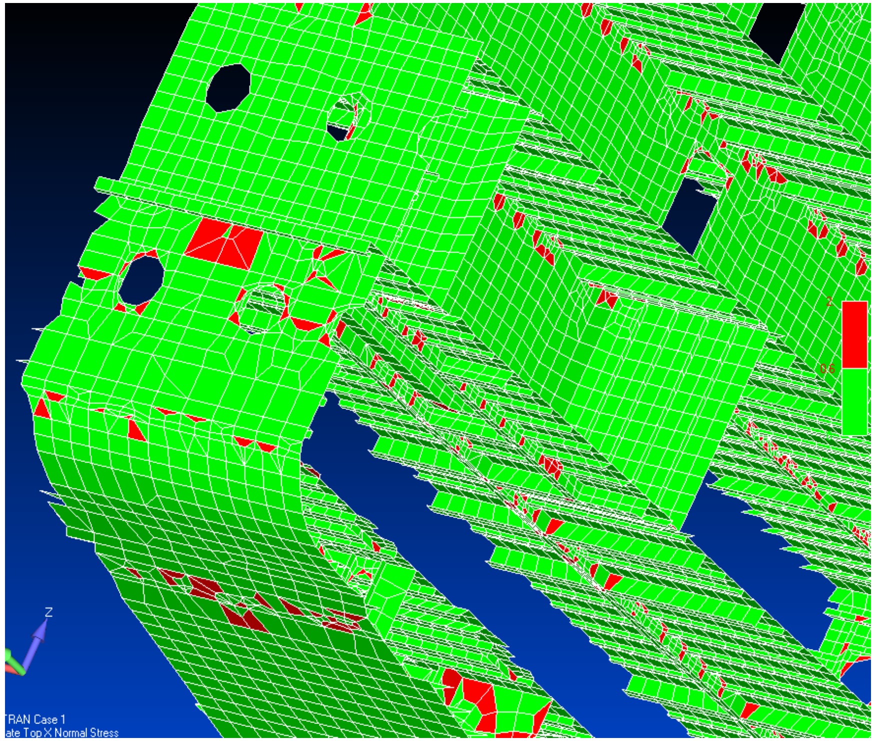




Proposal of New Formula

Validation:

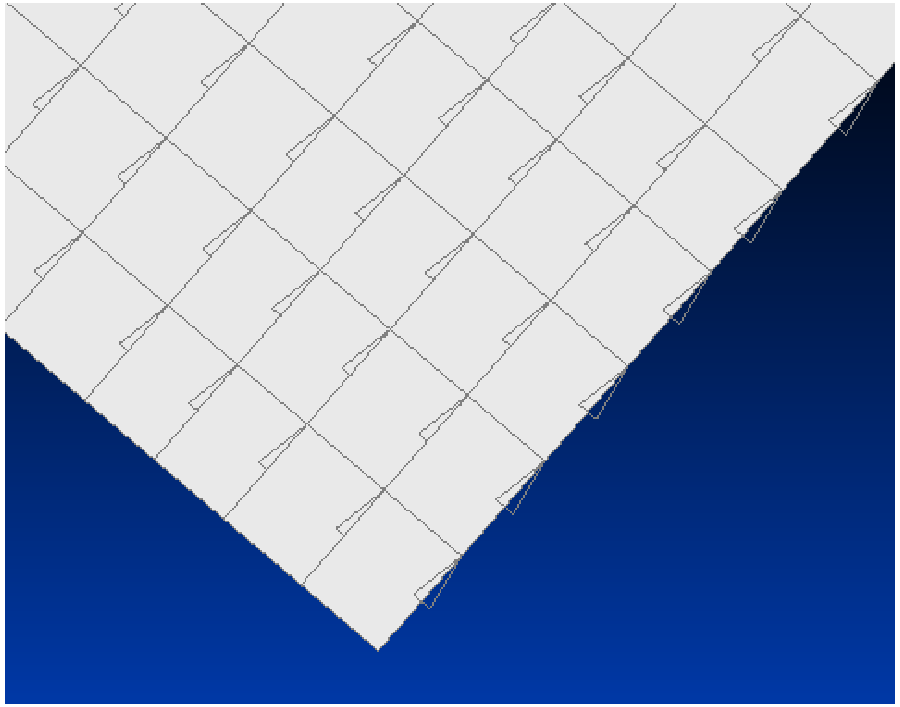




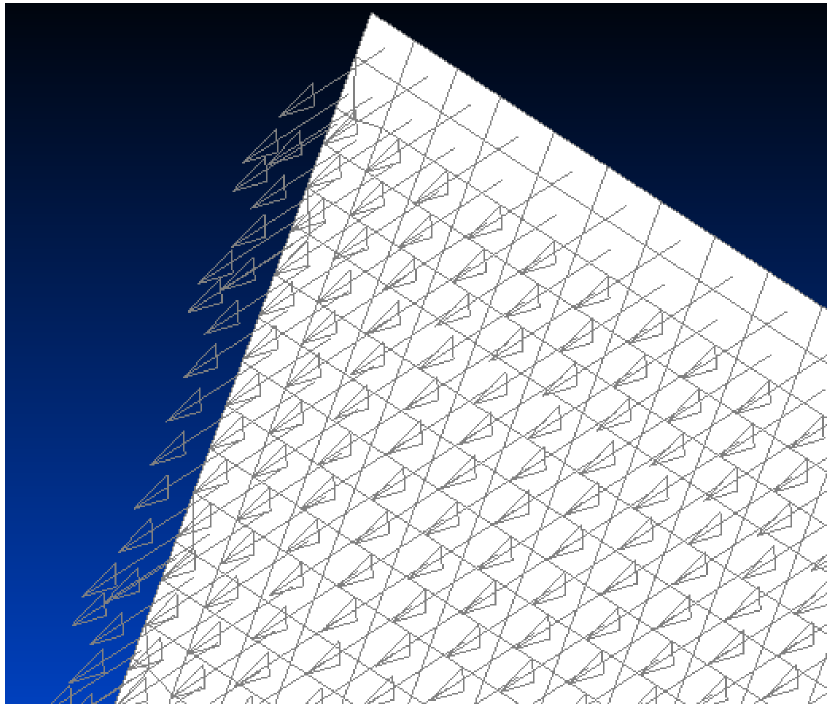
Manual/Non-geometric meshing: smooth mesh size transition & mesh size aspect ratio

Proposal of New Formula

Validation:



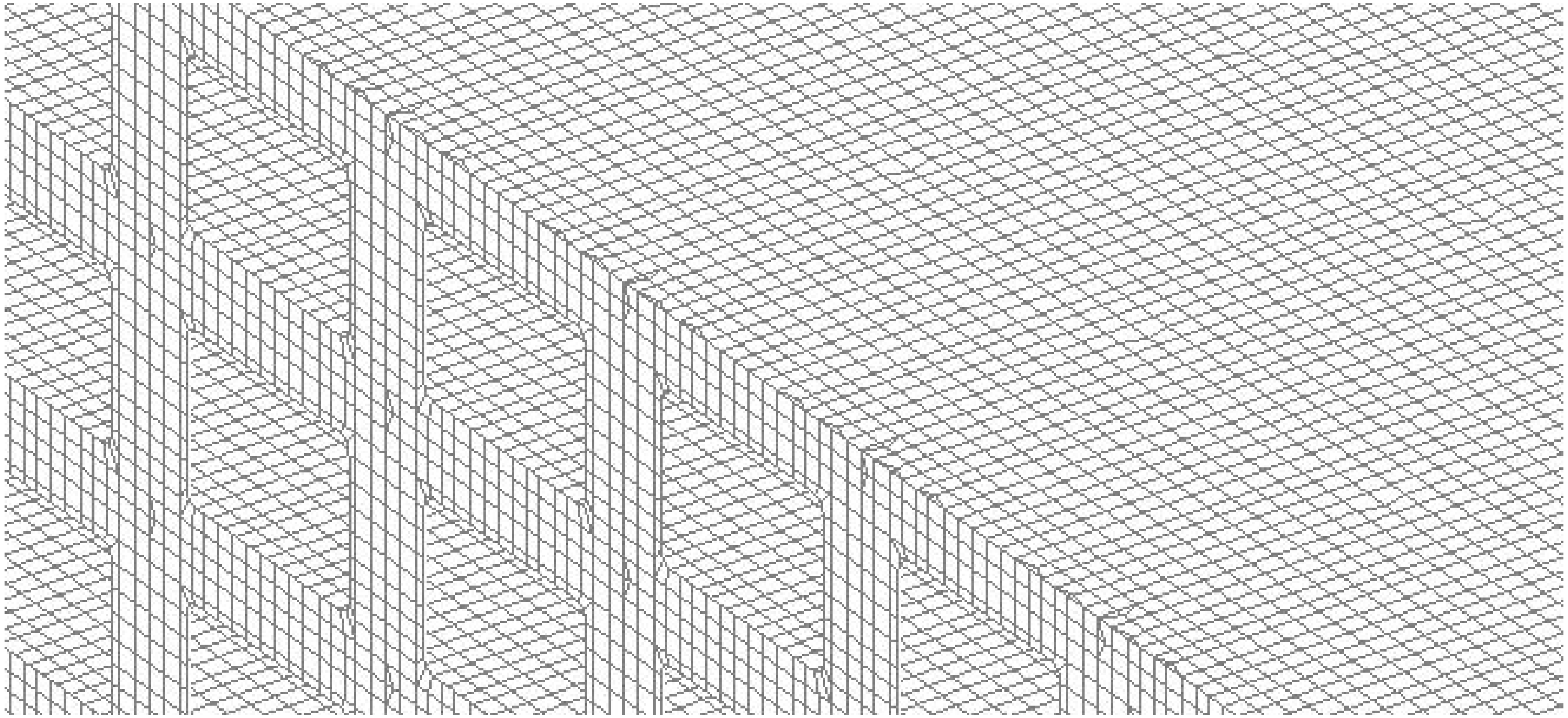
Normal Vectors



Right hand rule first edge

Proposal of New Formula

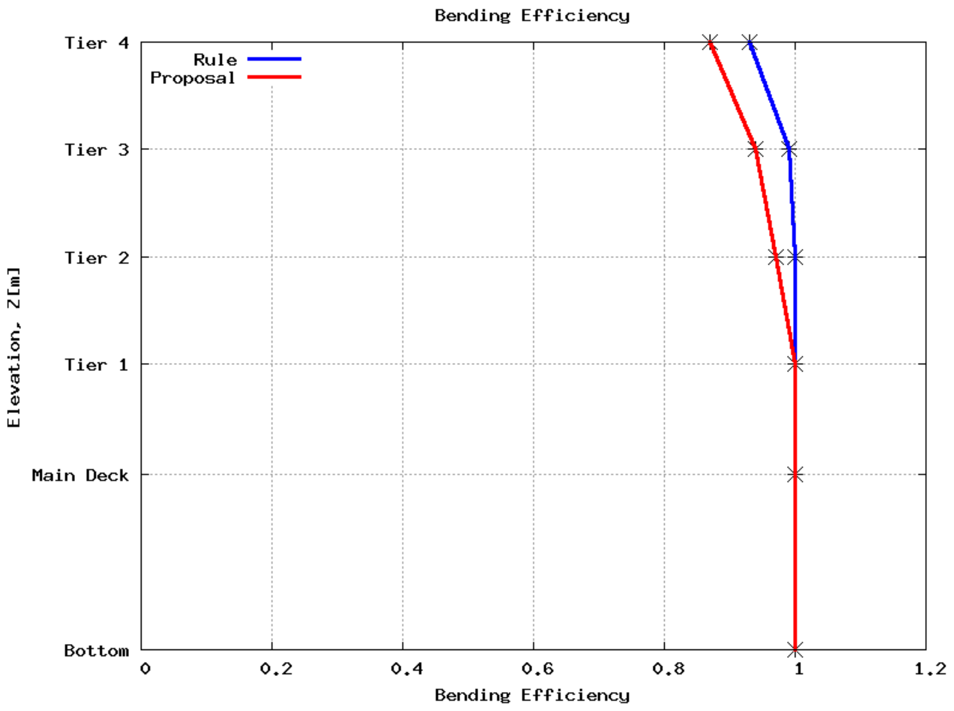
Validation:

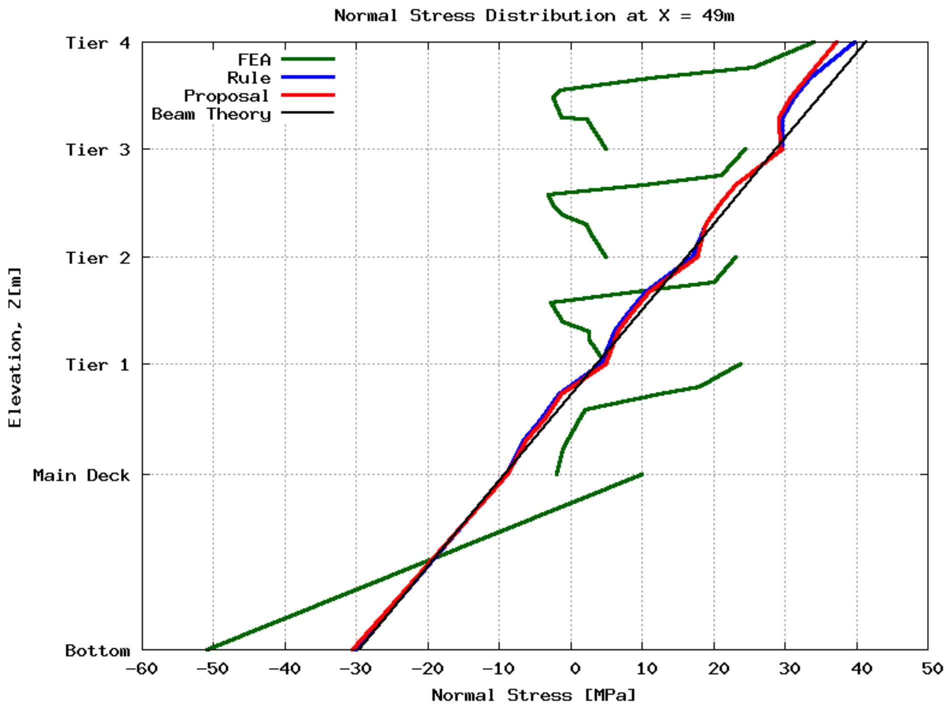


Most of the mesh are quadrilateral

Proposal of New Formula

Validation:



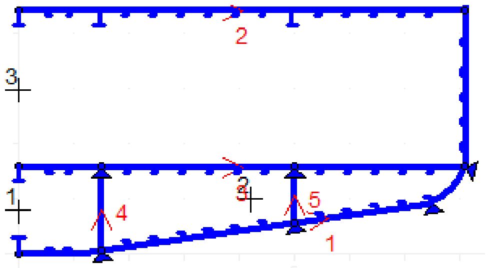


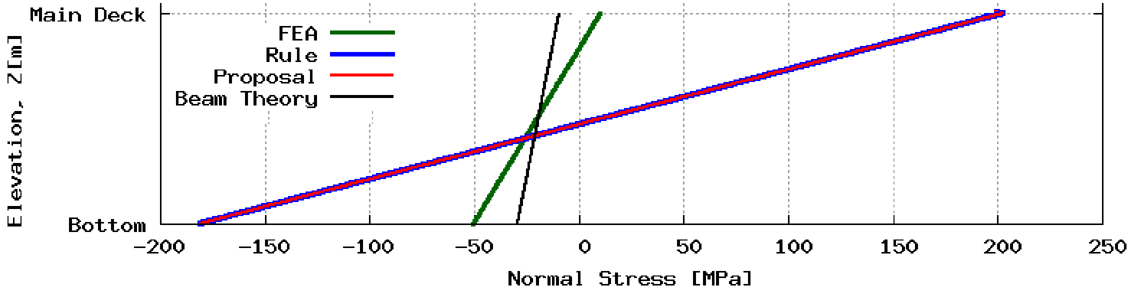
Application

Hull Girder Normal Stresses:

1) Stress Calculation in Main hull

- ✓ Cross-section of 'hull' is modeled in Marsinland, not the full vessel.
- ✓ Bending moment for full vessel should be applied at this model to obtain the normal stresses at hull.





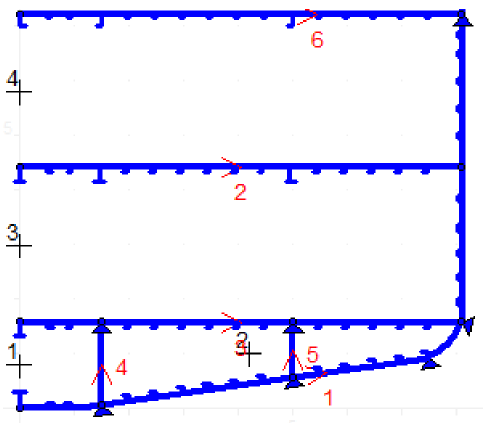
Application

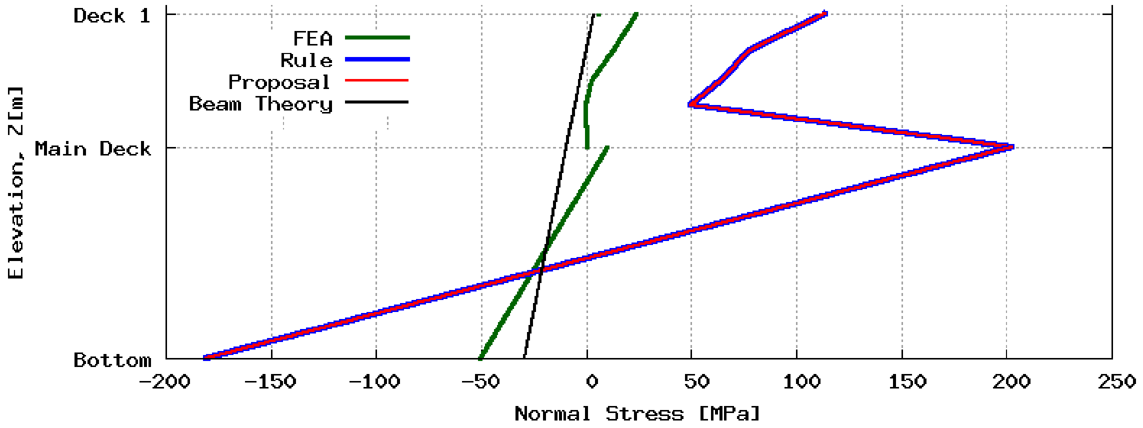
Hull Girder Normal Stresses:

2) Stress Calculation in Tier 1

✓ Cross-section of 'hull' and 'tier1' are modeled in Marsinland, not the full vessel.

✓ Bending moment for full vessel should be applied at this model to obtain the normal stresses at tier 1.



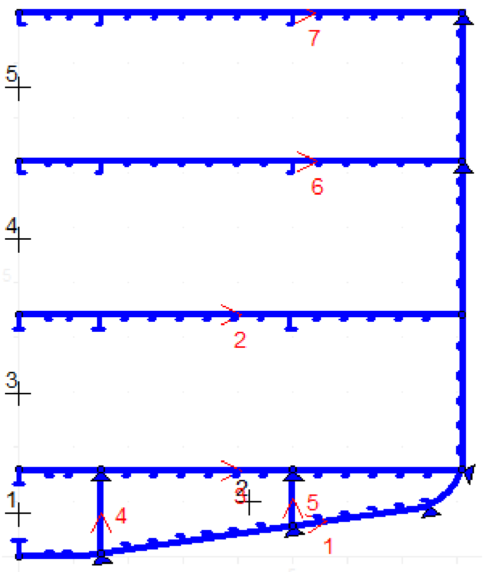


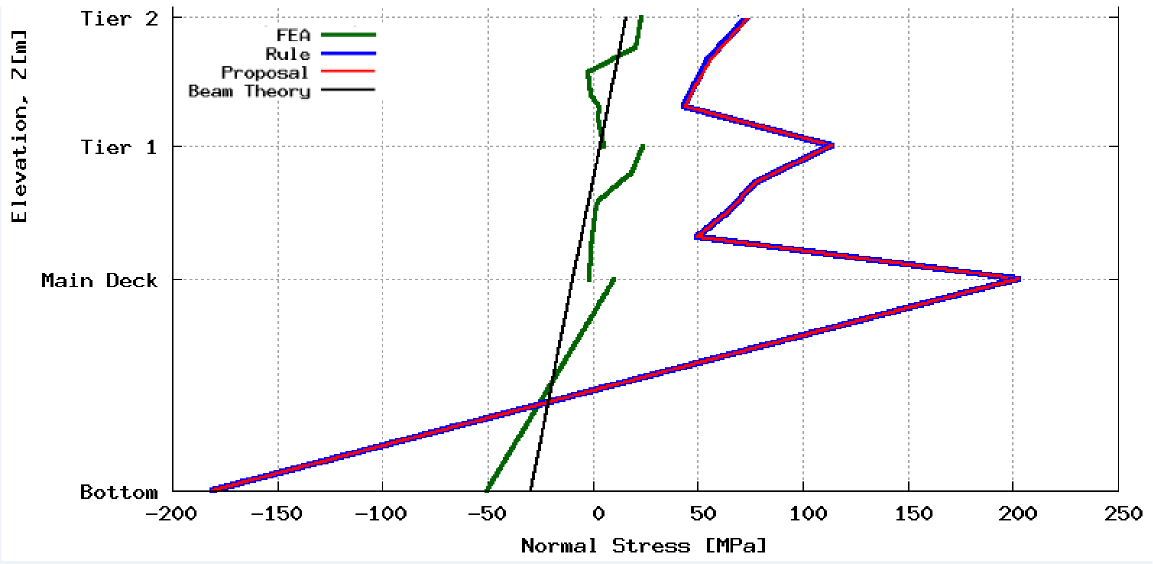
Application

Hull Girder Normal Stresses:

3) Stress Calculation in Tier 2

- ✓ Cross-section of 'hull‘, ‘tier 1’ and ‘tier 2’ are modeled in Marsinland, not the full vessel.
- ✓ Bending moment for full vessel should be applied at this model to obtain the normal stresses at tier 2.



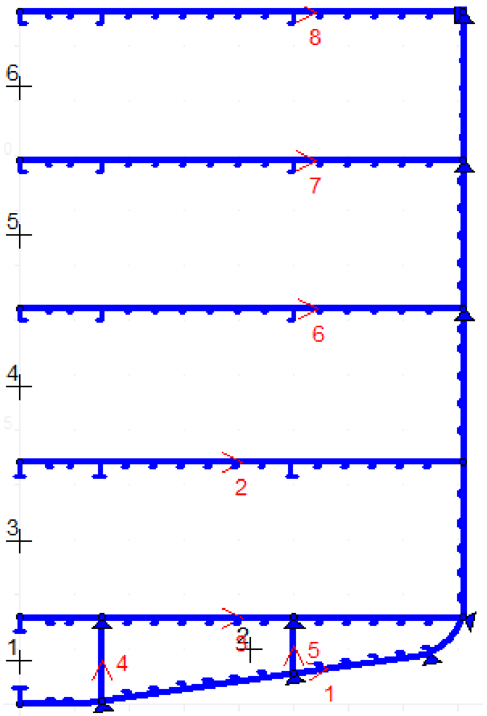


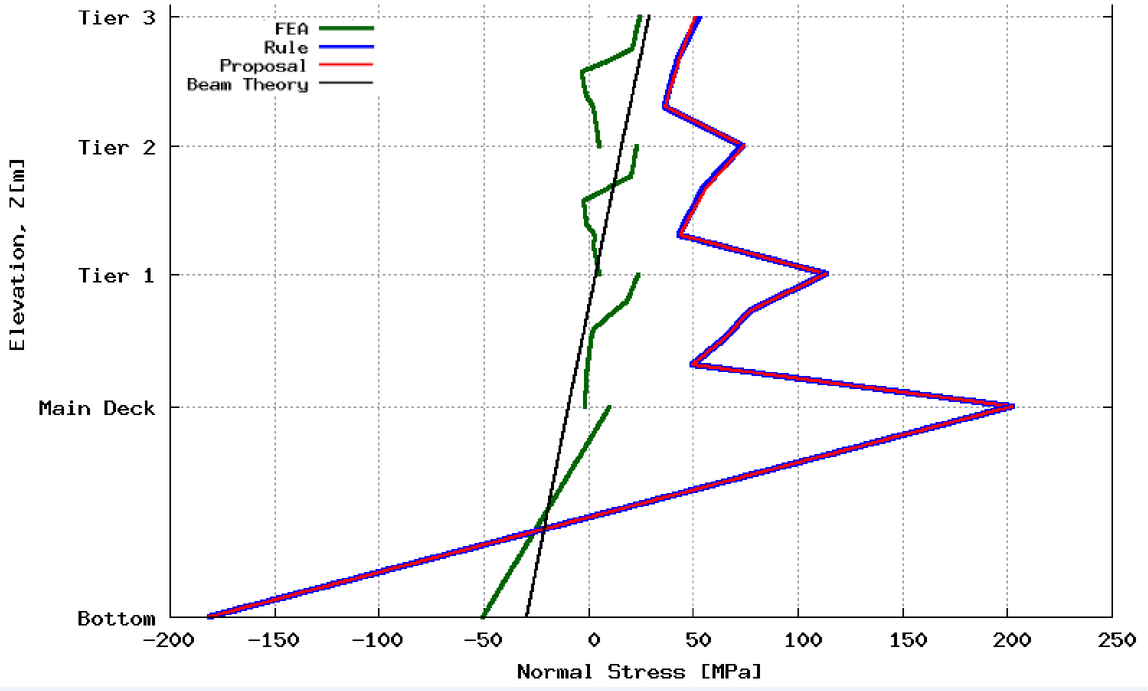
Application

Hull Girder Normal Stresses:

4) Stress Calculation in Tier 3

- ✓ Cross-section of 'hull', 'tier 1', 'tier 2' and 'tier 3' are modeled in Marsinland, not the full vessel.
- ✓ Bending moment for full vessel should be applied at this model to obtain the normal stresses at tier 3.



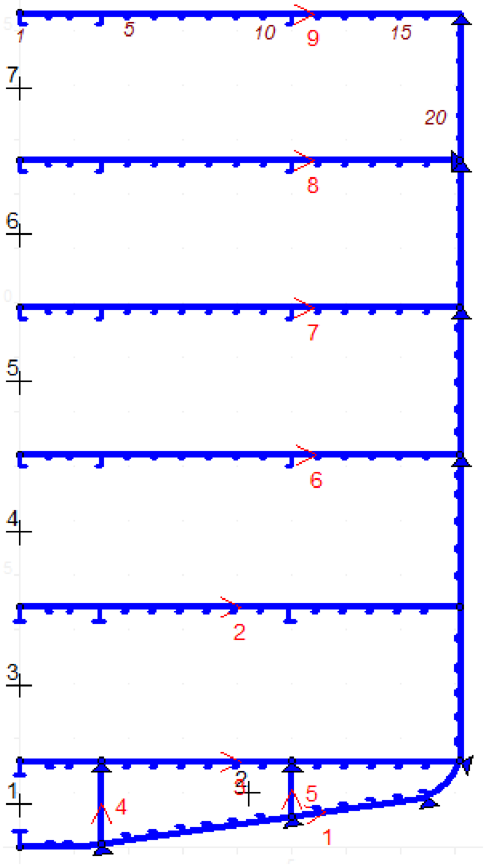


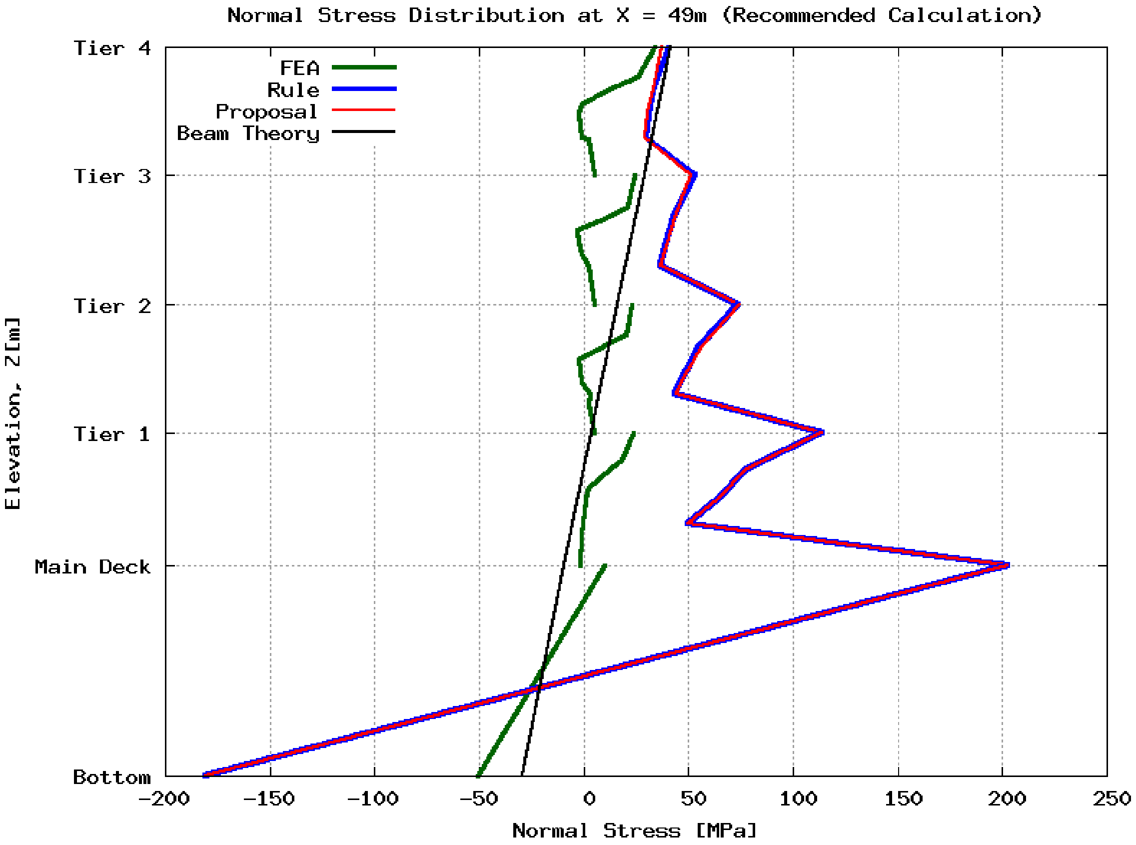
Application

Hull Girder Normal Stresses:

5) Stress Calculation in Tier 4

- ✓ Cross-section of 'hull', 'tier 1', 'tier 2', 'tier 3' and 'tier 4' are modeled in Marsinland, not the full vessel.
- ✓ Bending moment for full vessel should be applied at this model to obtain the normal stresses at tier 4.

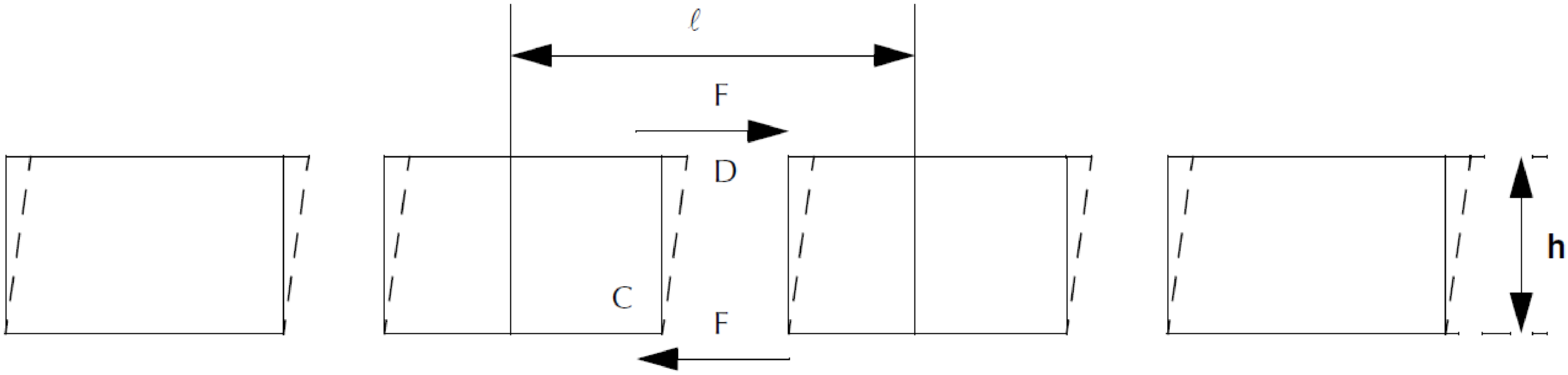




Application

Local Shear Force in Way of Window Style:

- ✓ Usually passenger vessels have large windows or side openings.
- ✓ The hull girder loads induce a force ‘F’ tending to deform the window stile as the girder is clamped at the lower end and its upper end moves horizontally



Application

Local Shear Force in Way of Window Style:

Step 1: Calculation of vertical shear force, $\mathbf{T_S}$

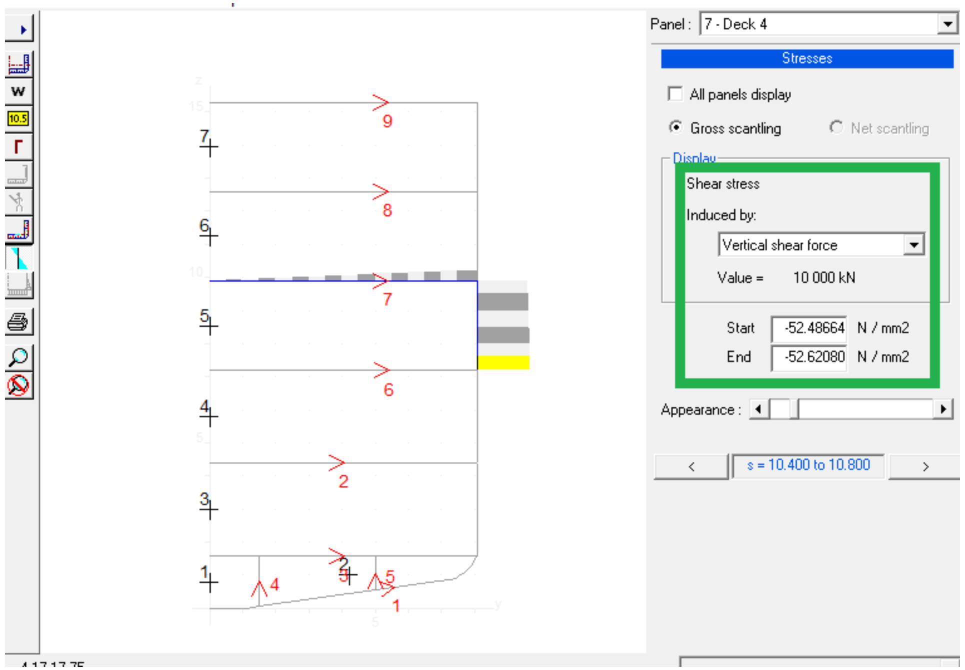
✓ NR 217 (Pt B, Ch 3, Sec 2): $T_S = \pi \frac{M}{L}$

Step 2: Calculation of shear stress, τ

✓ Marsinland is useful

Step 3: Calculation of horizontal shear force, F

✓ NR 217 (Pt D, Ch 1, Sec 6): $F = \frac{\tau}{2} \cdot t \cdot \ell$



Conclusion

Overall findings and improvements:

a) Investigation of hull-superstructure interaction

- ✓ Influence of superstructure length to hull length (r_L)
- ✓ Influence of superstructure deck openings to total deck area (r_D)
- ✓ Influence of superstructure side openings to total lateral area (r_S)
- ✓ Influence of side opening locations

b) Proposal of new formula for bending efficiency

- ✓ A new expression of bending efficiency – more accurate

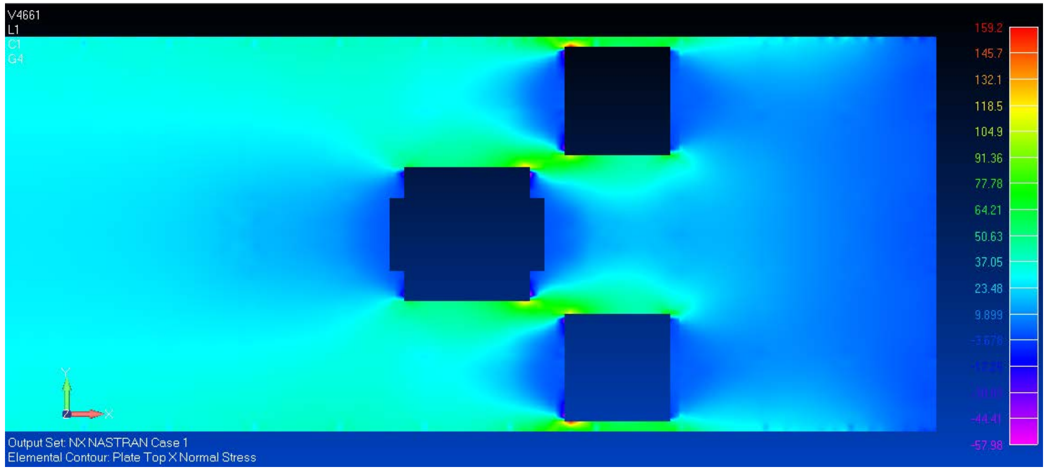
c) Development of guidelines

- ✓ Hull girder normal stresses
- ✓ Local shear force on way of window stiles

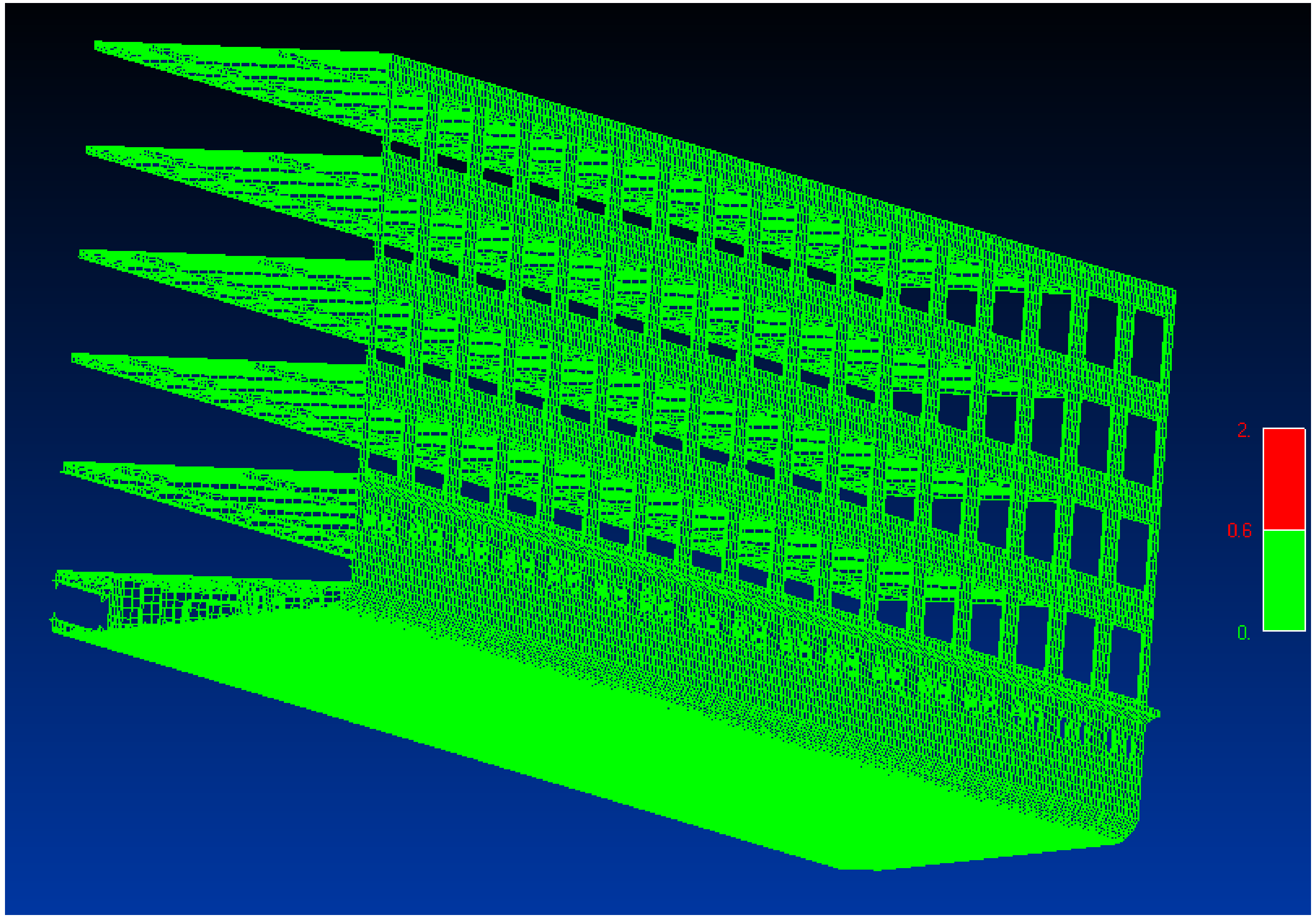
Conclusion

Further Recommendations:

- ✓ Fore and aft part of the ship
- ✓ Structural details i.e. swimming pool, Jacuzzi, manholes etc.
- ✓ Other curves of Schade's design chart (ωλ = 2.5, 2.0, 1.5 & 1.0)
- ✓ Influence of r_L for short superstructures ($r_L < 0.25$, M. Mano et al., 2009)
- ✓ Influence of superstructure deck openings to total deck area (r_D)



Question and Answers?!



Thank you for your attention!