Investigation of the Hull-Superstructure Interaction in order to Predict the Contribution of Superstructures to Hull Girder Strength

EMSHIP Master Thesis Presentation

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Outline

- Introduction
- Hull and Superstructure Interaction Problem
- Ship Structure and Rule Based Analysis
- Strength Analysis by Using Finite Element Analysis Software
- Analysis and Results
- Concolusion and Recommendation

Introduction

- Passenger ships have strong hull and superstructure interaction
- The main hull and superstructure contribute fully to the longitudnal strength
- Larege openings in the side shell and decks, the load transfer from the recession of the side shell make the structural behavior complex

Design and Rule Requirement Conflicts

Design Requirements for Large Openings

Structural Safety with Large Openings

Objective

- Predict the structural behavior of superstructure in FEA and compare the rule based analysis results

Studied Ship

- Omar El Khayam
- Operated on Lake Nasser in Egypt
- One of Largest Inland Cruise Ships BV has classed

General Description of the Ship

Identification	Top
Register Number:	09827J
Ship Name:	OMAR EL KHAYAM
Type & service:	Passenger vessel
Owner:	TRAVCO NILE CRUISES
Connecting District:	ALEXANDRIA (ALX)
Flag:	EGYPT
Port of Registry:	CAIRO

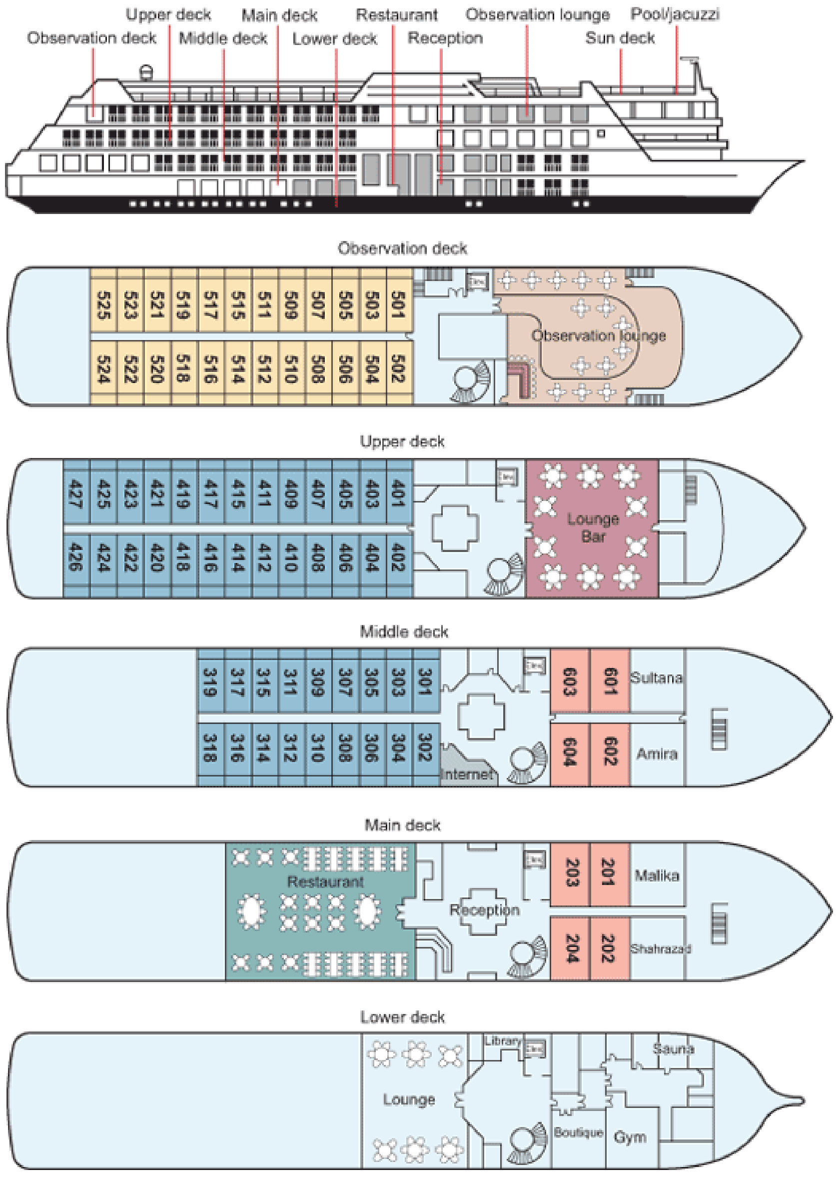
Machinery	Top
Propelling Type:	Diesel
Licence:	CATERPILLAR
Date of Build:	01 Jun 2005
Builder:	CATERPILLAR, Inc.
Place of Build (country):	Mossville (Illinois) (USA)
Power and rating	
Total Power (kW):	1710 kW
Total Power (HP):	2325 HP
Propelling machinery	
Internal Combustion Engine:	(3) 4T - 12 cyl - 13.72 cm x 15.24 cm at 2100 rpm
Electrical installation	
Frequency:	50 Hz
Propellers and propellershafts	
Propelling system:	2 Screw Propeller Solid Ord 10.00 1 Screw Propeller Solid Ord 10.00 at 719 rpm

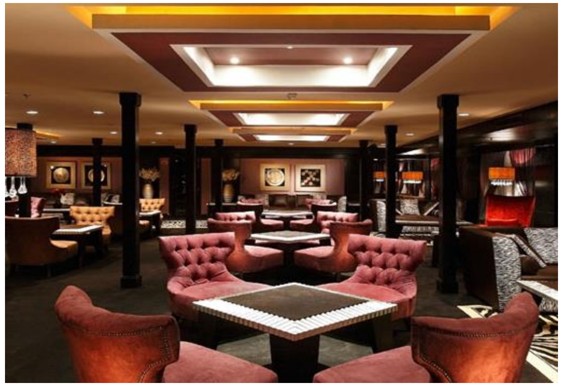
Classification	Top
Main Class Symbols:	I 3/3 E
Service Notations:	✠ Passenger vessel
Navigation Notations:	NI1
Machinery:	● MACH
Equipment:	1(Ch 32 Q2)

Dimension	Top
Gross Tonnage 69:	2096 (Estimated)
Overall Length:	112 m
LPP:	98 m
Breadth:	16.2 m
Depth:	4.4 m
Draught:	2.2 m

Hull & Cargo	Top
Builder:	Port Said Engineering Works
Place of build (Country):	Port Said (EGY)
Date of Build:	01 Dec 2008
Hull Material:	Steel
Number of Cont. Decks:	Machinery Aft
Tanks	
LBC:	6985

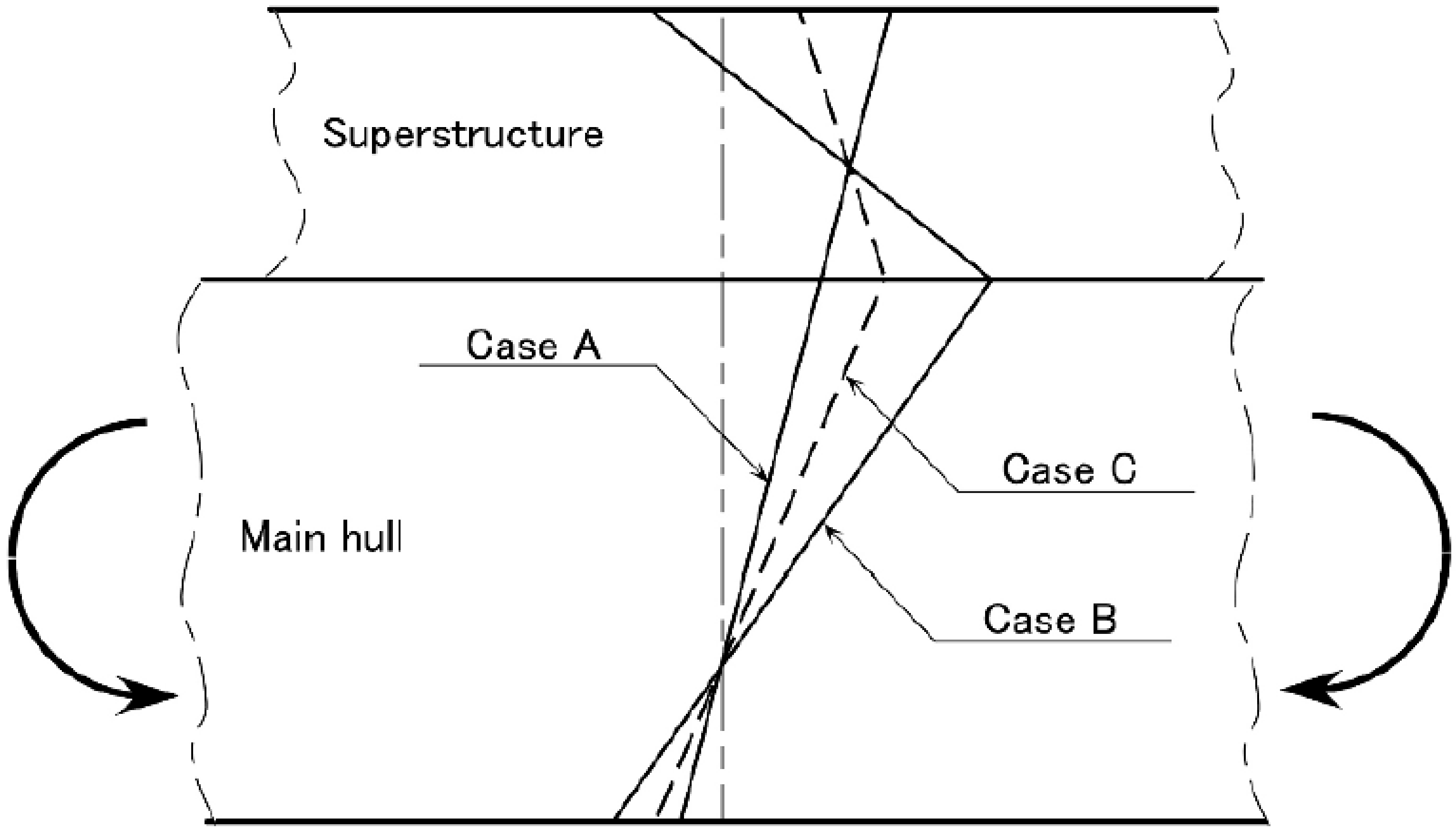
General Description of the Ship





Hull and Superstructure Interaction Problem

- Hull Superstructure Bending Stress Distribution



Hull and Superstructure Interaction Problem

- Case A: Superstructure is long enough
  Stress in linear form
- Case B: Superstructure is short
  Significant vairance in hull and deckhouse
- Case C: Intermediate case

When the superstructure is 15%-20% length of main hull, it can be regarded as a relatively long superstructure

Hull and Superstructure Interaction Problem

- Bending Efficiency

A parameter indicating the contribution degree of an erection to the hull girder strength

- Factors Affecting Bending Efficiency

Ship geometry, Connections, Hull section modulus, Materials and Opening Size

- Hull Girder Strength

Based on simple beam theory

- Net Scantling

Gross thickness deduct the Corrosion thickness

$$\sigma_1 = \frac{M_{TH}}{Z} 10^3$$

Hull and Superstructure Interaction Problem

Bending Efficiency

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

		A	I	e	A_{SH}	Ω	j	λ	χ	ν
		[cm²]	[cm⁴]	[cm]	[cm²]	[cm⁻⁴]	[cm⁻¹]	[m]	[-]	[-]
Deck 3	1	7630.7	2.00E+08	235.2	403.3	1.97E-08	6.87E-04	26.875	1.85	56.69%
	e	1846.5	2.64E+06	340.9	73.5					
Deck 4	1	8528.8	5.29E+08	416	476.8	2.24E-08	7.52E-04	47.65	3.58	50.41%
	e	1721.7	2.35E+06	259.5	76					
Deck 5	1	10250.5	1.19E+09	572.6	552.8	1.82E-08	6.45E-04	45.5	2.94	39.98%
	e	1695.1	2.07E+06	260.6	66.5					
Deck 6	1	11945.6	2.20E+09	724.3	619.3	1.89E-08	5.66E-04	42.45	2.4	27.71%
	e	1265.8	1.47E+06	260.7	47.5					

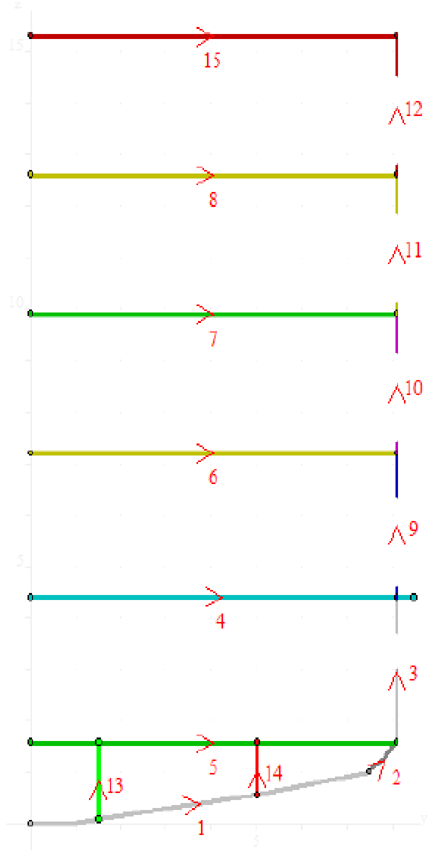
Ship Structure Details

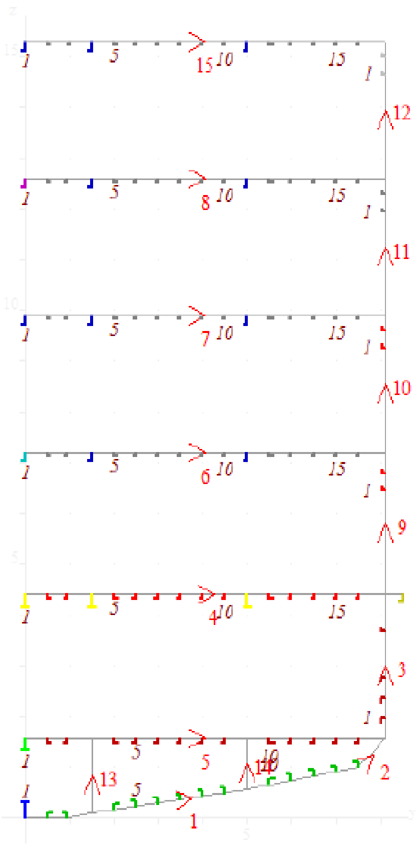
- Longitudinaly framed (mainly)
- Fore and aft part transversely framed
- Double bottom Structure
- Swimming Pool and Jacuzzi
- Large balcony

- *Material: Grade A normal strength steel*

Rule Based Analysis

- Five frame locations are modeled in MARS INLAND
- Stress distribution is checked without bending efficiency
- Stress distribution is calculated considering bending efficiency after
- Frame locations: 32m, 37m, 46m, 50m and 73m





Rule Based Analysis

Structural item	Z, [m]	Simple beam theory	NR 217	
		σ_{x1}	□□v[%]□□□	σ_{x2}
Bottom	0	-32.37	100	-30.04
Inner Bottom	1.6	-24.14	100	-22.55
Main Deck	4.4	-9.76	100	-9.06
Deck 3	7.2	4.63	56.69	2.44
Deck 4	9.9	18.50	50.41	8.66
Deck 5	12.6	32.38	39.98	12.01
Deck 6	15.3	46.25	27.71	11.89

Strength Analysis by Using Finite Element Analysis Software

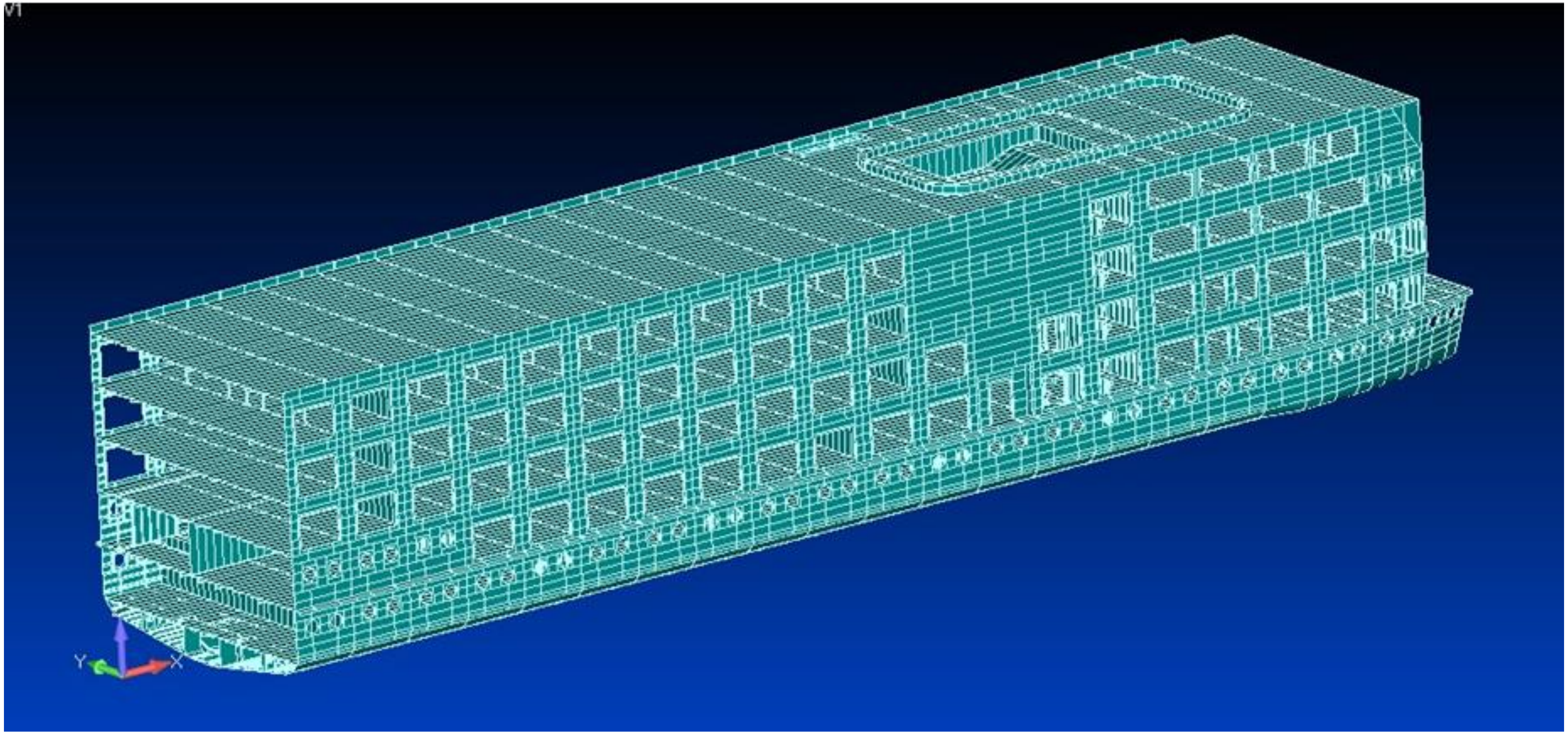
- Software: FEMAP
- Elements:

  Plate/Shell Elements for Plates and Stiffeners

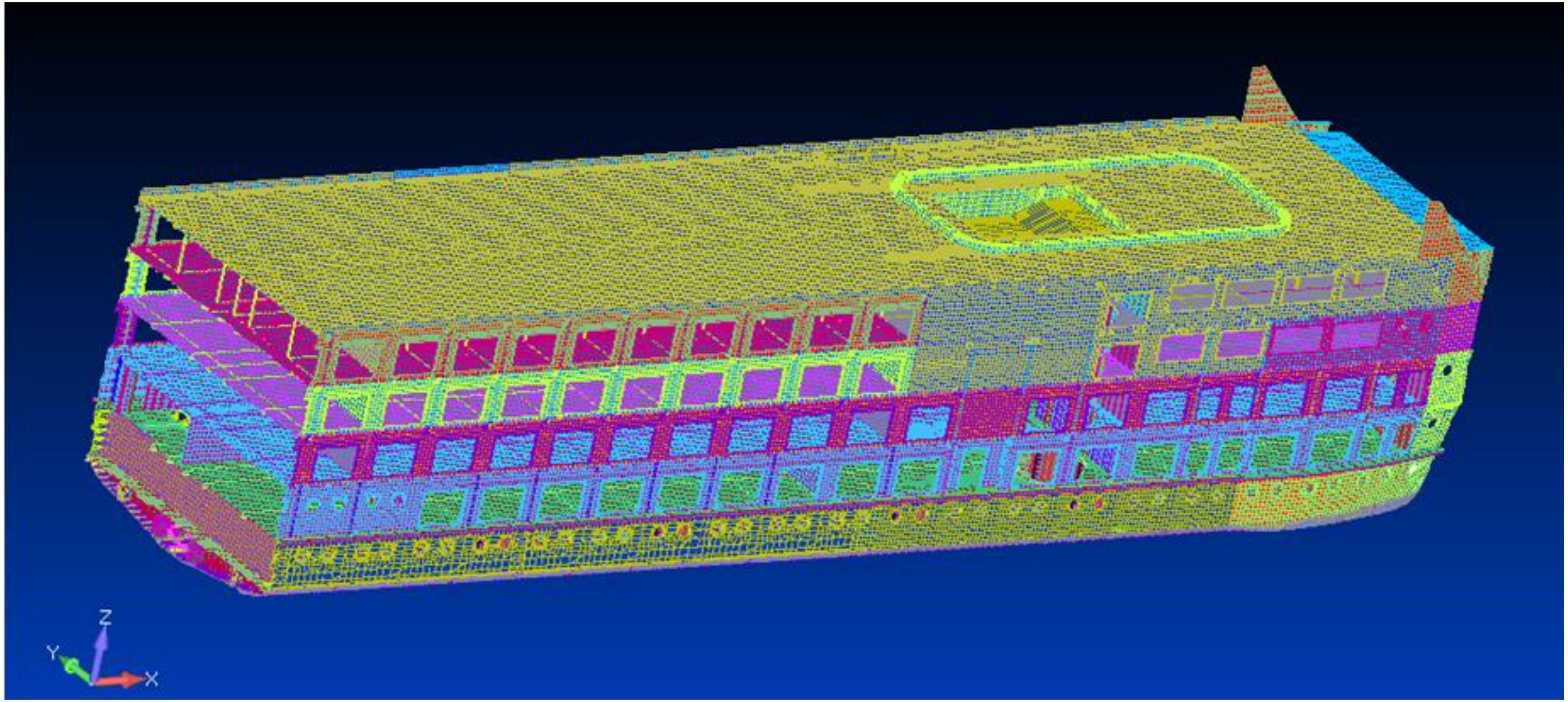
  Rigid element for the application of loads

- Structural details are included except some brackets which do not participate in the hull girder bending

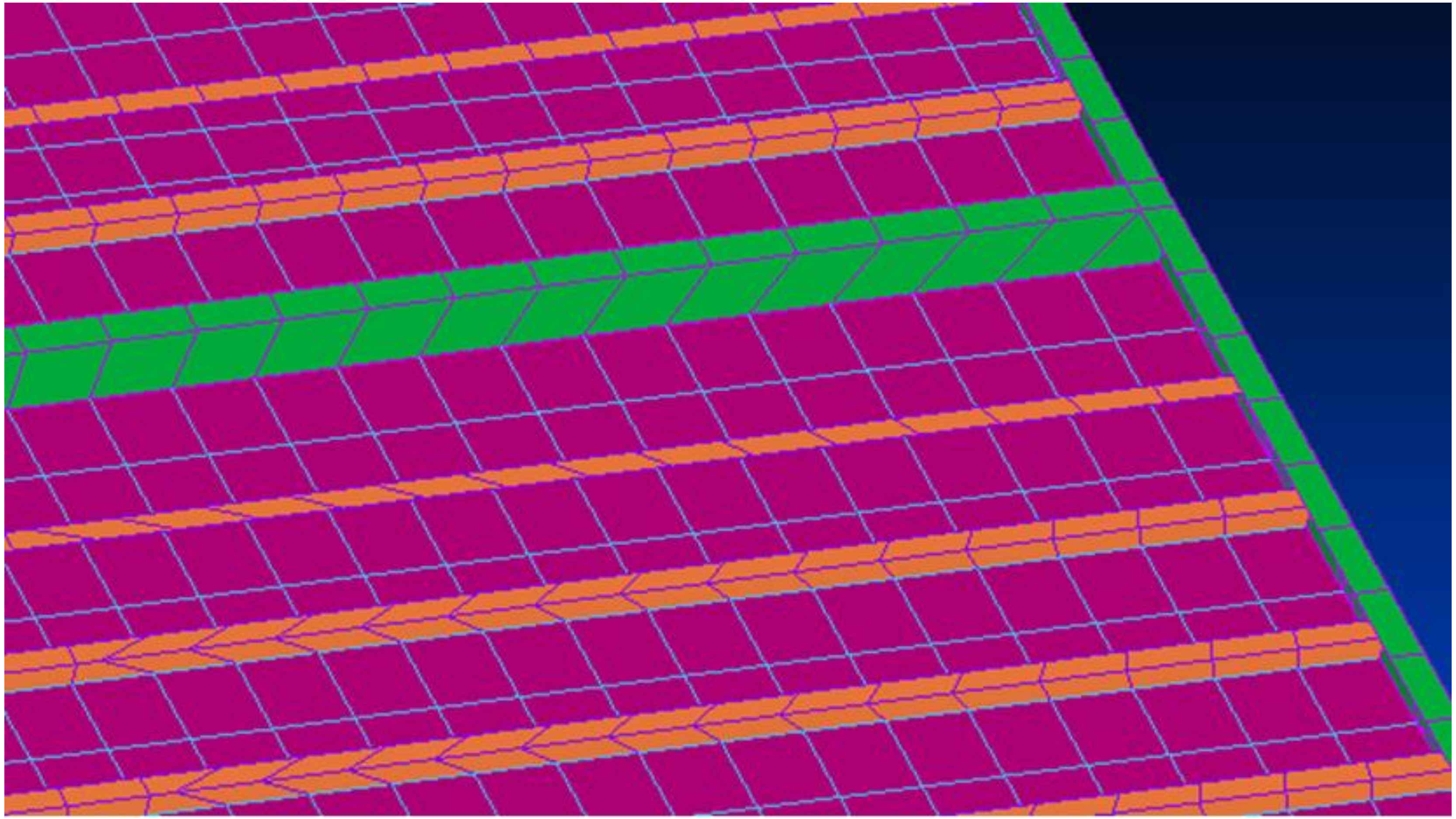
Strength Analysis by Using Finite Element Analysis Software



Strength Analysis by Using Finite Element Analysis Software

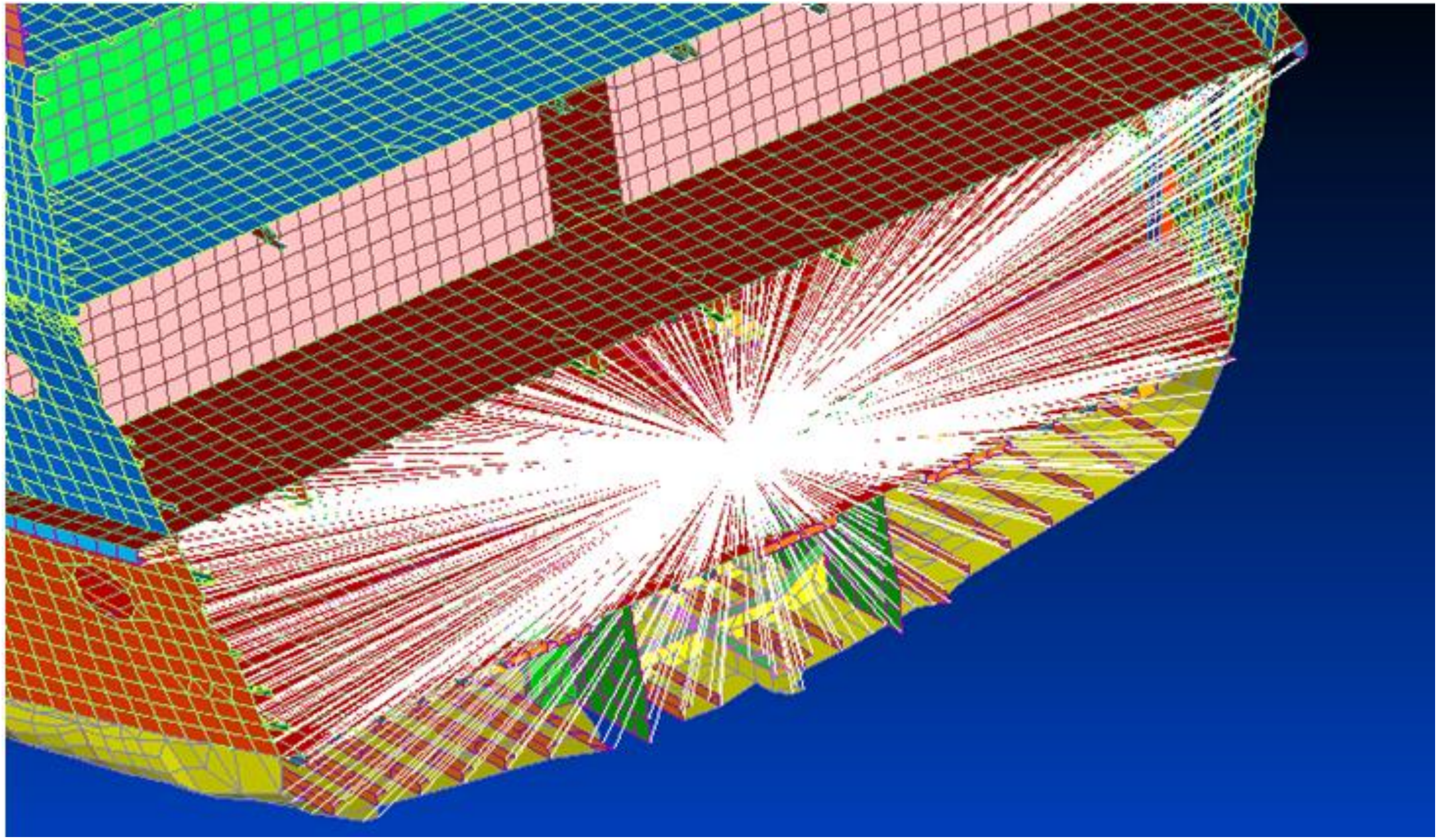


Strength Analysis by Using Finite Element Analysis Software



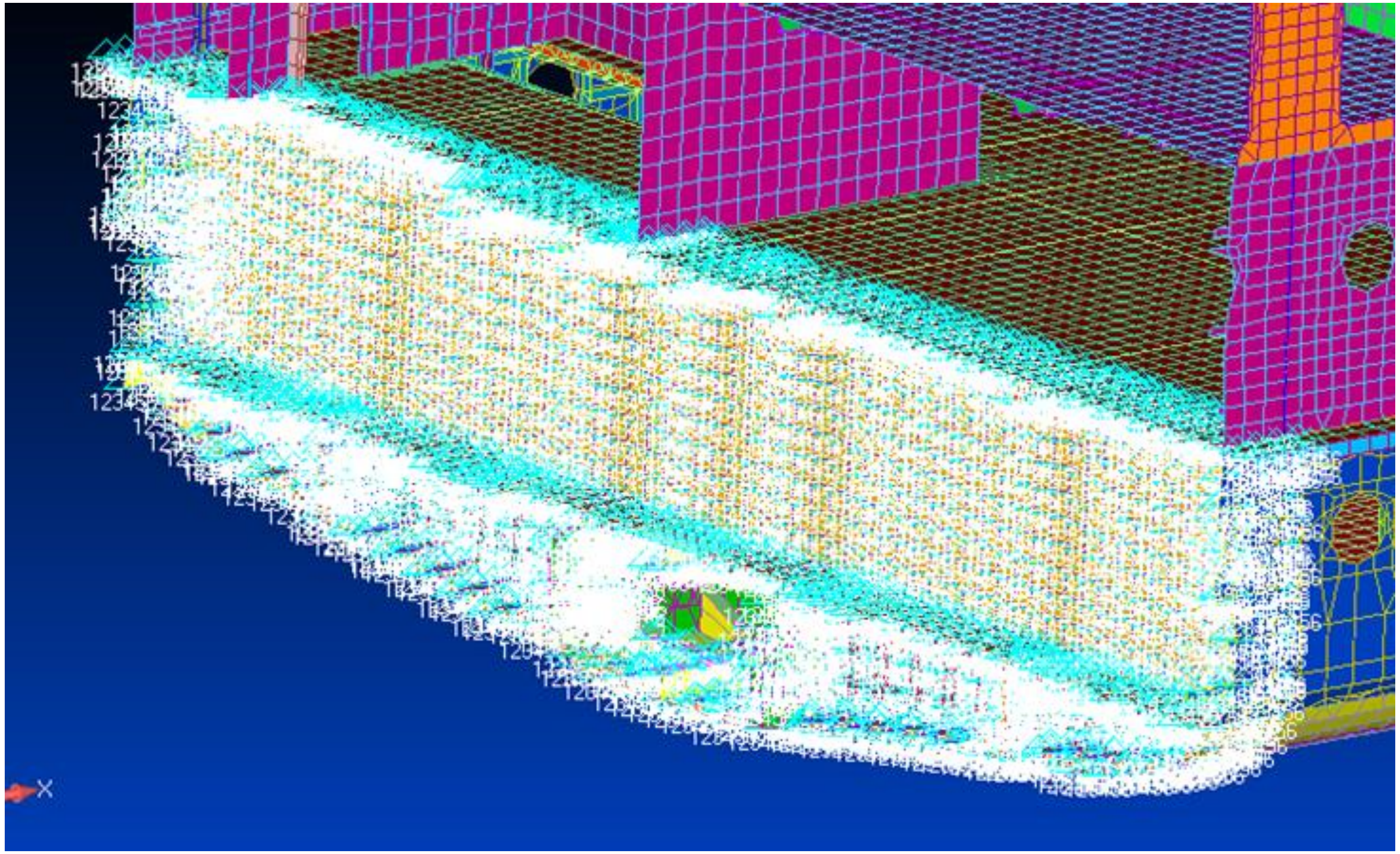
Strength Analysis by Using Finite Element Analysis Software

Rigid Element



Strength Analysis by Using Finite Element Analysis Software

Boundary Condition



Strength Analysis by Using Finite Element Analysis Software

Loads

- According to BV Inland Rules, the calculation should be based on hull girder bending moment induced by still water bending and wave bending moments
- Sagging condition should not be considered

Still water hogging bending moment

$$M_{H0} = 0.273L^2B^{1.342}D^{0.172}(1.265 - C_B) = 126317\text{kN.m}$$

Still water sagging bending moment

$$M_{s0} = 0$$

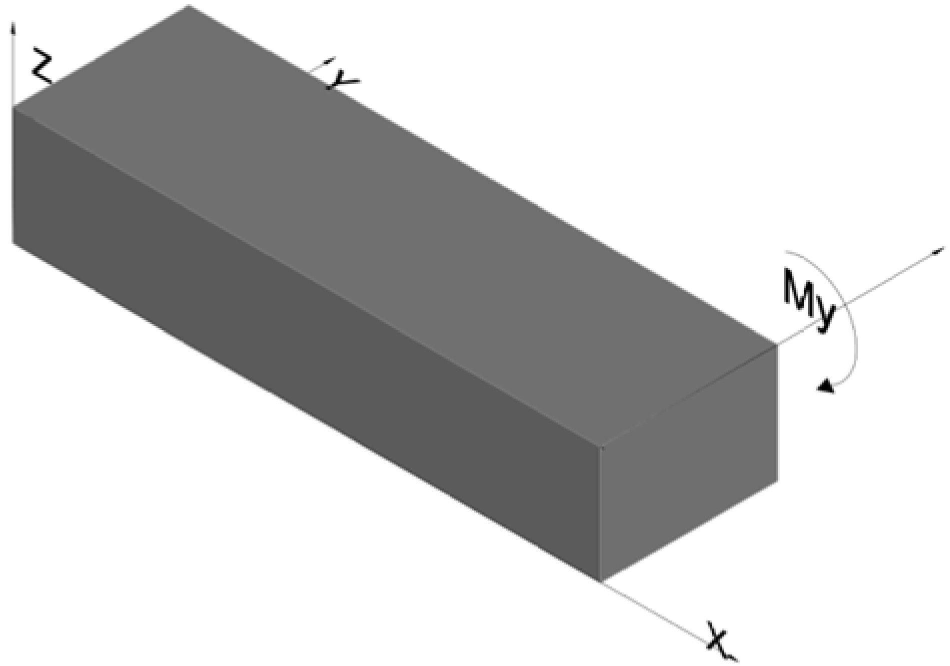
For range of navigation IN$(1.2 \le x \le 2)$, the absolute value of the wave-induced bending moment amidships is to be obtained as follows:

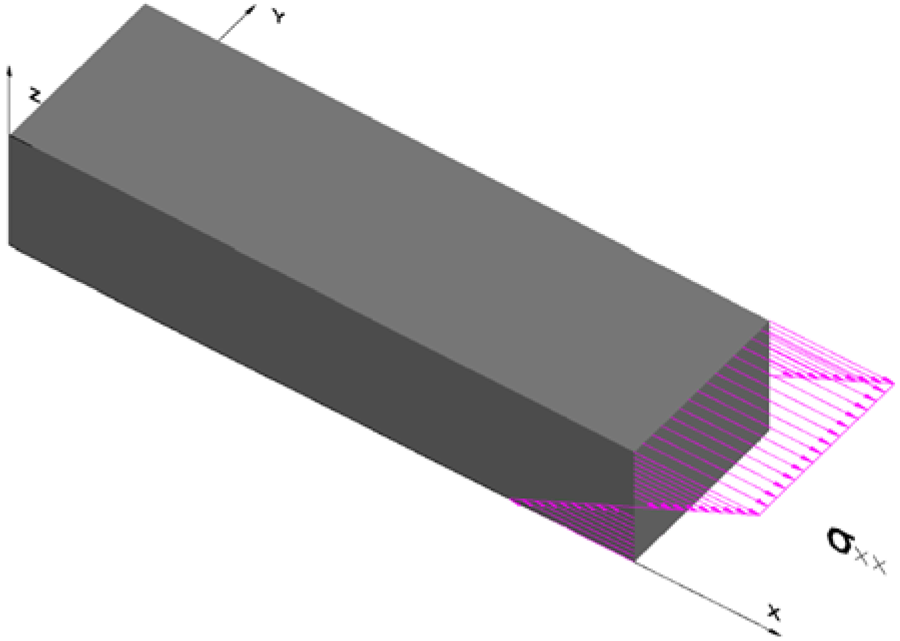
$$M_W = 0.021nCL^2B(C_B + 0.7) = 43692\text{kN.m}$$

The total bending moment for calculation is thus 170009kN.m or 1.7×10^{11}N.mm under hogging condition. The sagging condition is not considered.

Strength Analysis by Using Finite Element Analysis Software

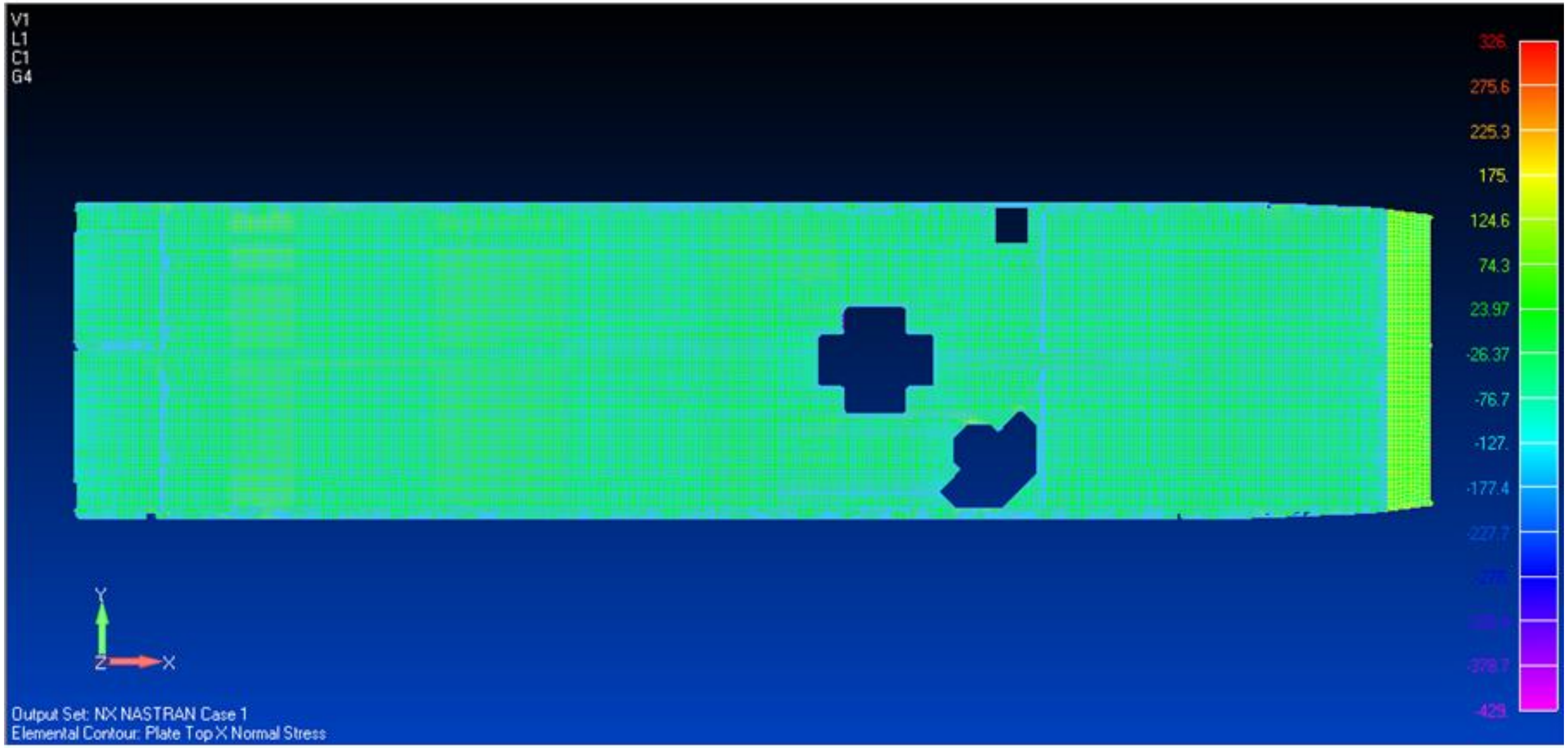
Model Simplification





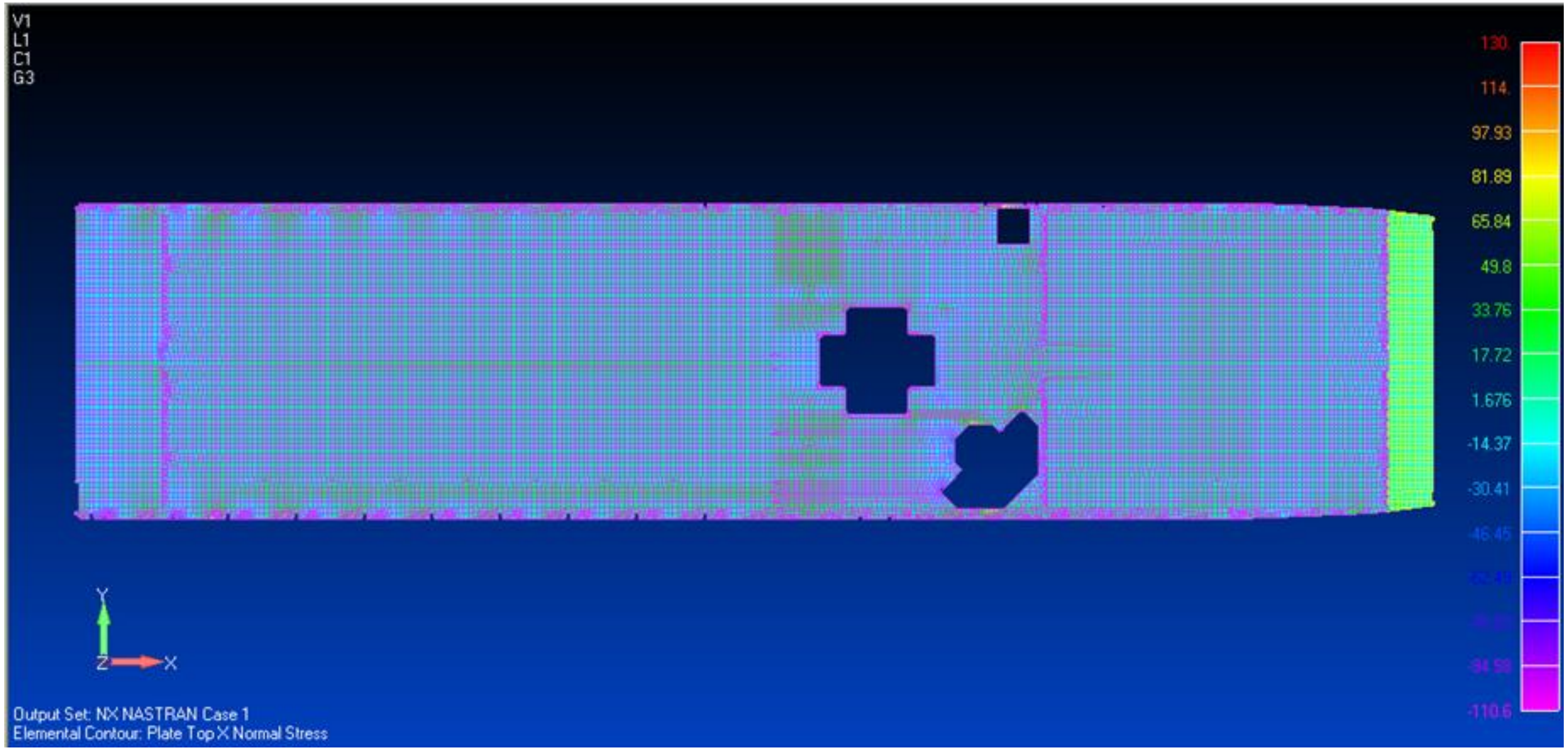
Analysis and Results

Deck 3 Level Stress



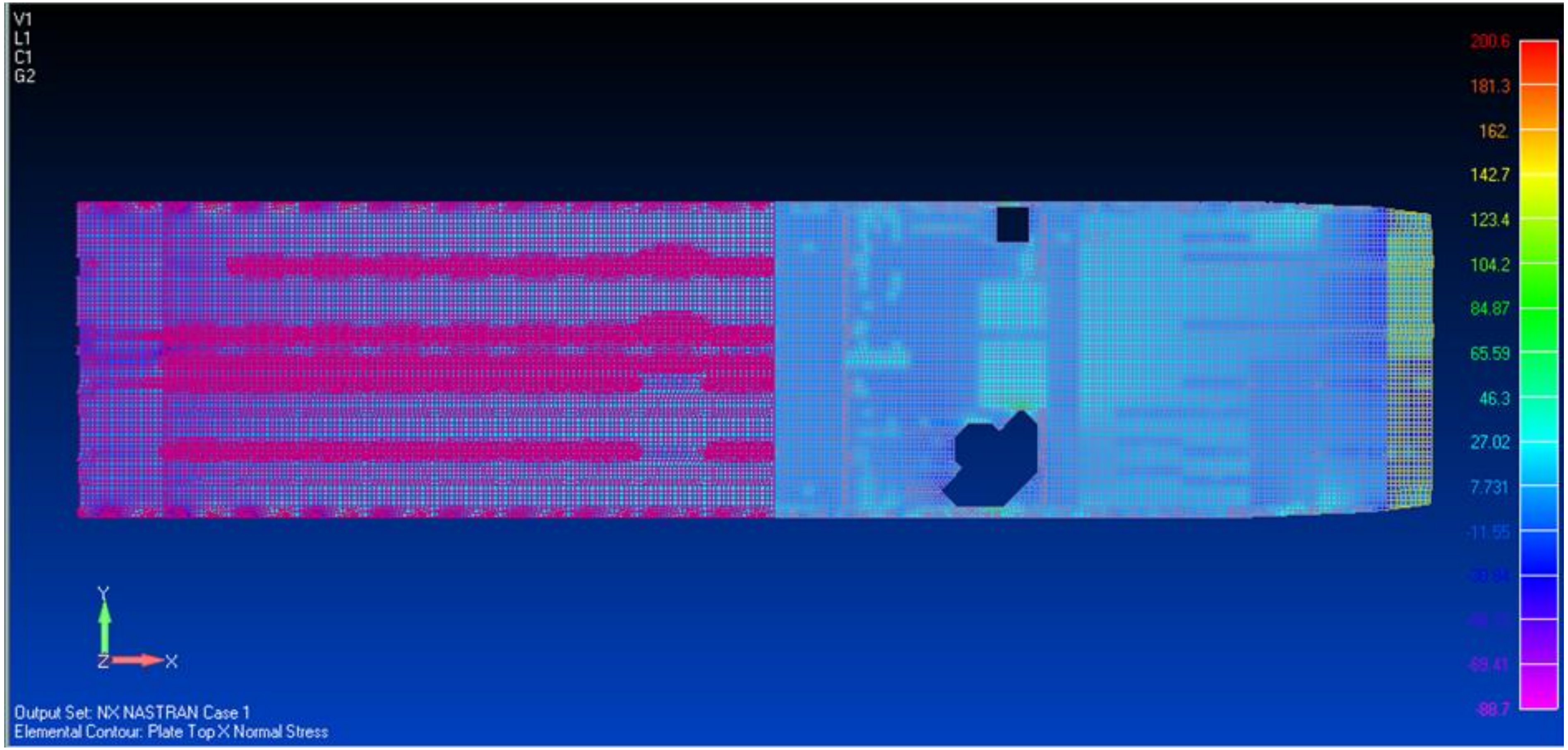
Analysis and Results

Deck 4 Level Stress



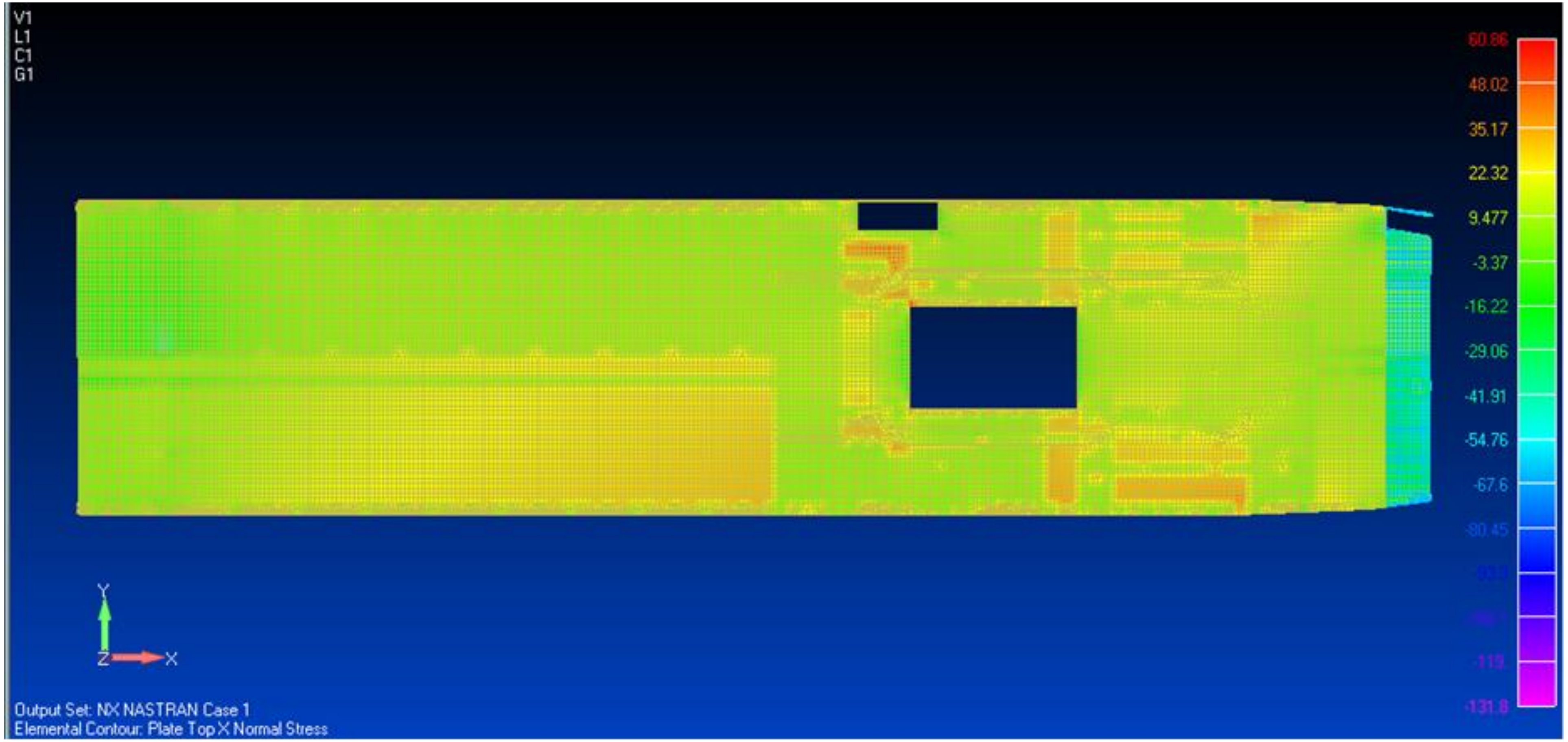
Analysis and Results

Deck 5 Level Stress



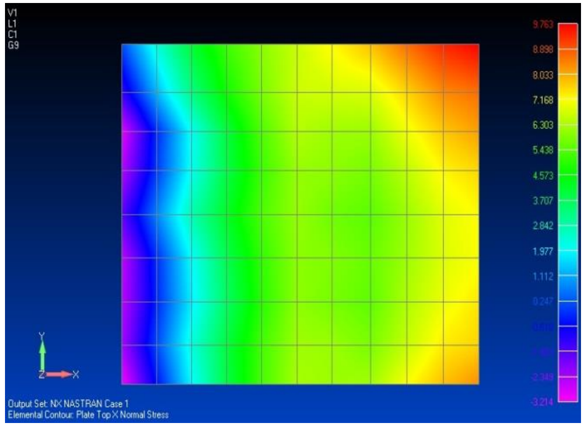
Analysis and Results

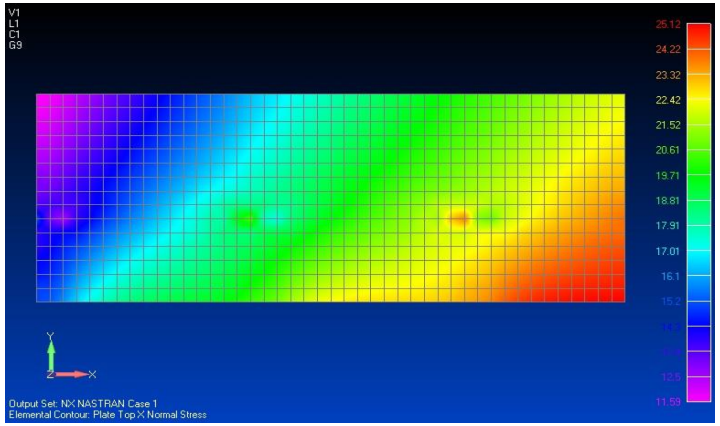
Deck 6 Level Stress

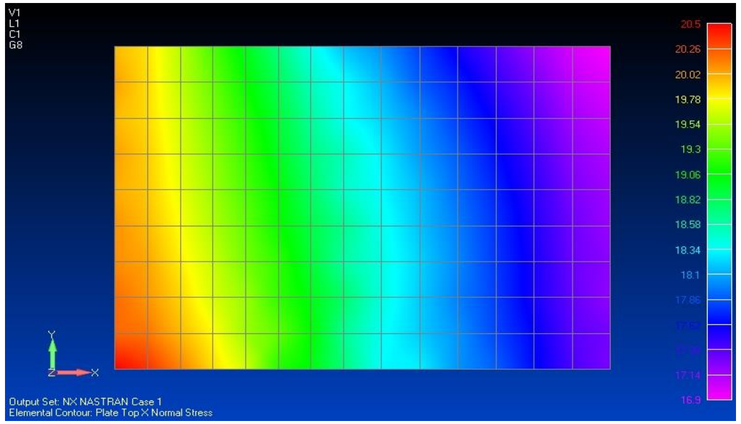


Analysis and Results

Details for Analysis







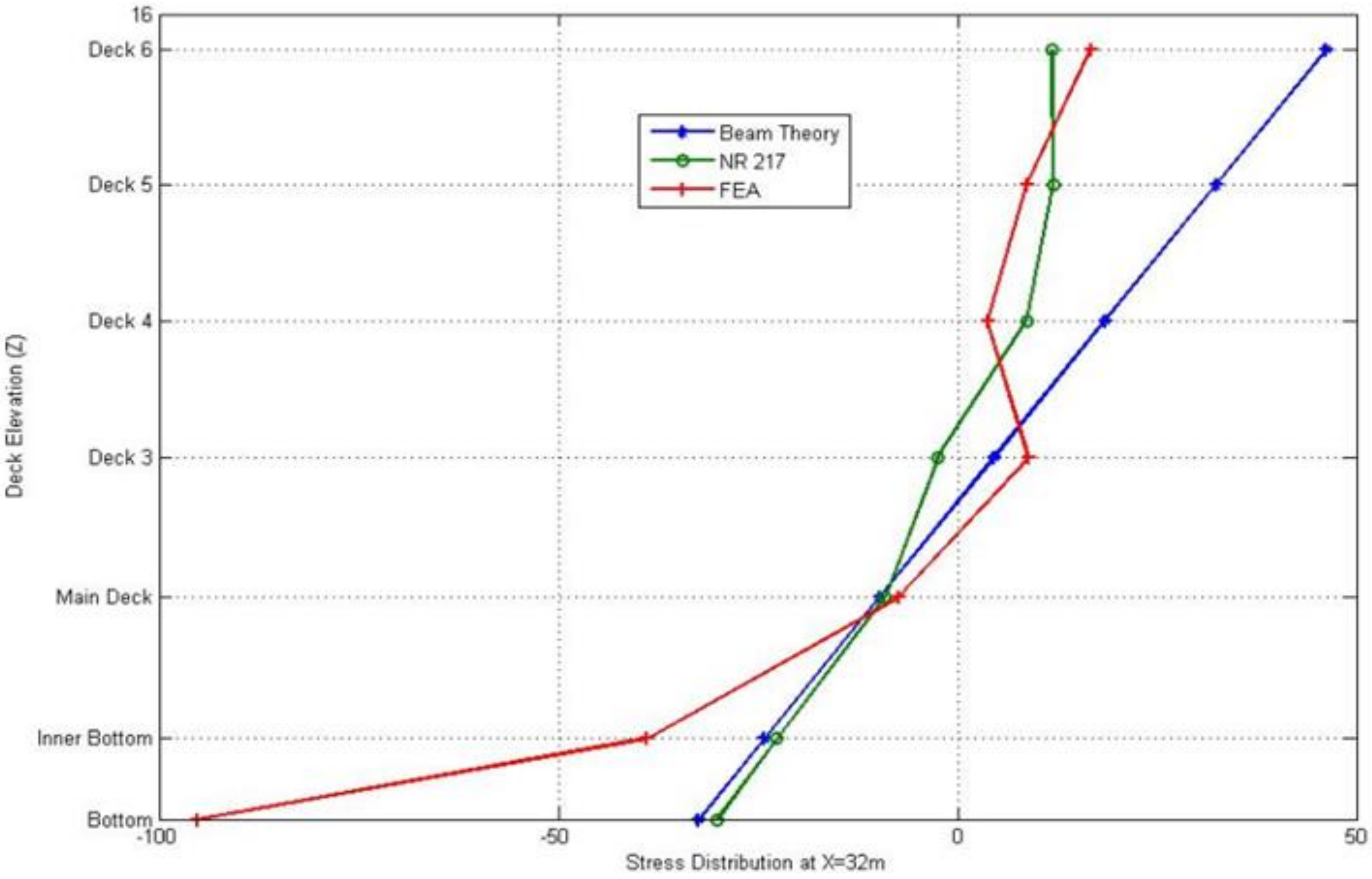
Analysis and Results

X=32m Results Comparison

Structural item	Z, [m]	Simple beam theory	NR 217		F.E.A
		σ_{x1}	□□v[%]□□ □	σ_{x2}	σ_{x3}
Bottom	0	-32.37	100	-30.04	-95.27
Inner Bottom	1.6	-24.14	100	-22.55	-38.9
Main Deck	4.4	-9.76	100	-9.06	-7.44
Deck 3	7.2	4.63	56.69	2.44	8.97
Deck 4	9.9	18.50	50.41	8.66	3.77
Deck 5	12.6	32.38	39.98	12.01	8.72
Deck 6	15.3	46.25	27.71	11.89	16.68

Analysis and Results

X=32m Results Comparison



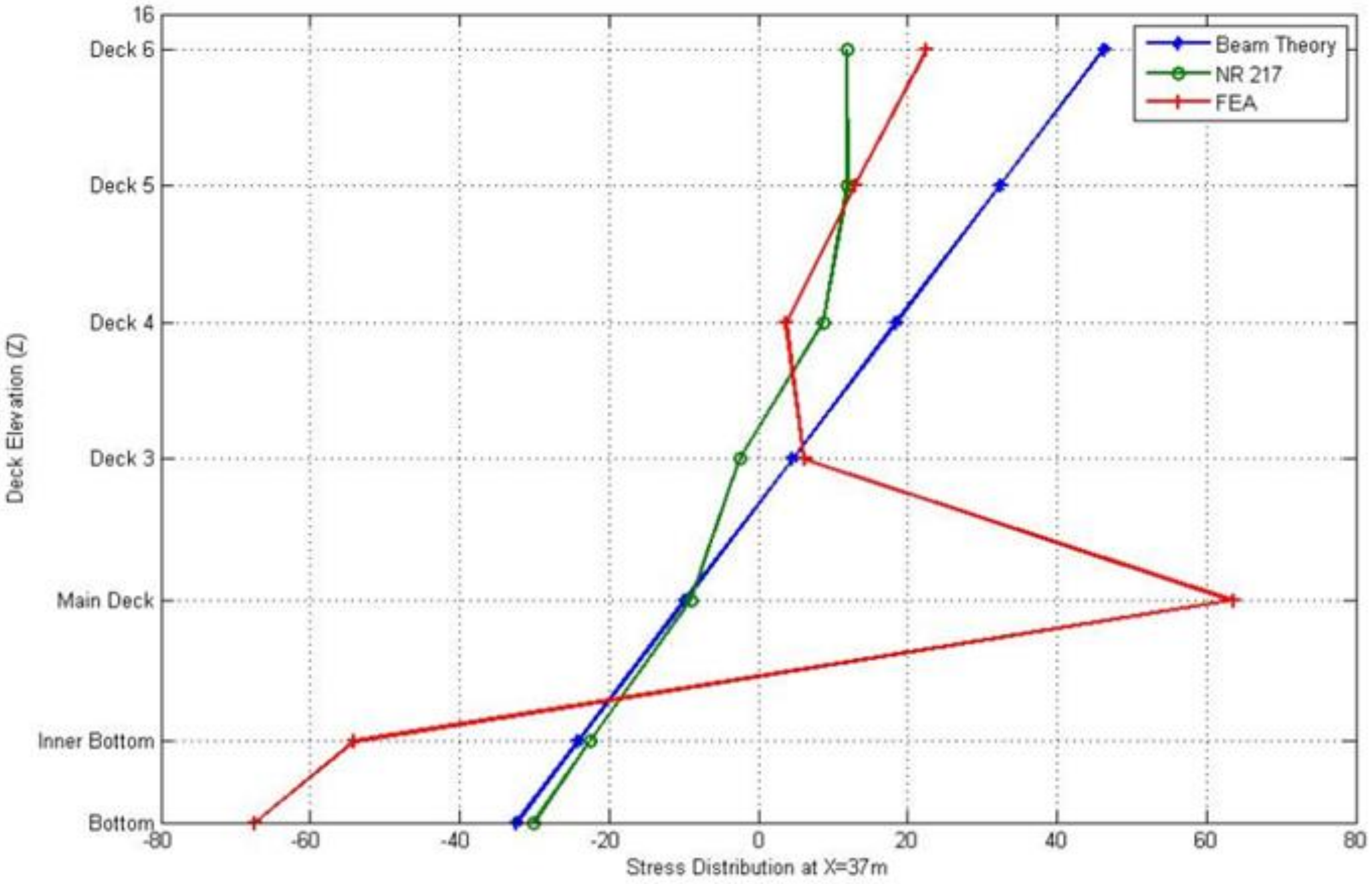
Analysis and Results

X=37m Results Comparison

Structural item	Z, [m]	Simple beam theory	NR 217		F.E.A
		σ_{x1}	□□v[%]□□ □	σ_{x2}	σ_{x3}
Bottom	0	-32.37	100	-30.04	-67.37
Inner Bottom	1.6	-24.14	100	-22.55	-54.15
Main Deck	4.4	-9.76	100	-9.06	63.61
Deck 3	7.2	4.63	56.69	2.44	6.22
Deck 4	9.9	18.50	50.41	8.66	3.76
Deck 5	12.6	32.38	39.98	12.01	12.9
Deck 6	15.3	46.25	27.71	11.89	22.58

Analysis and Results

X=37m Results Comparison



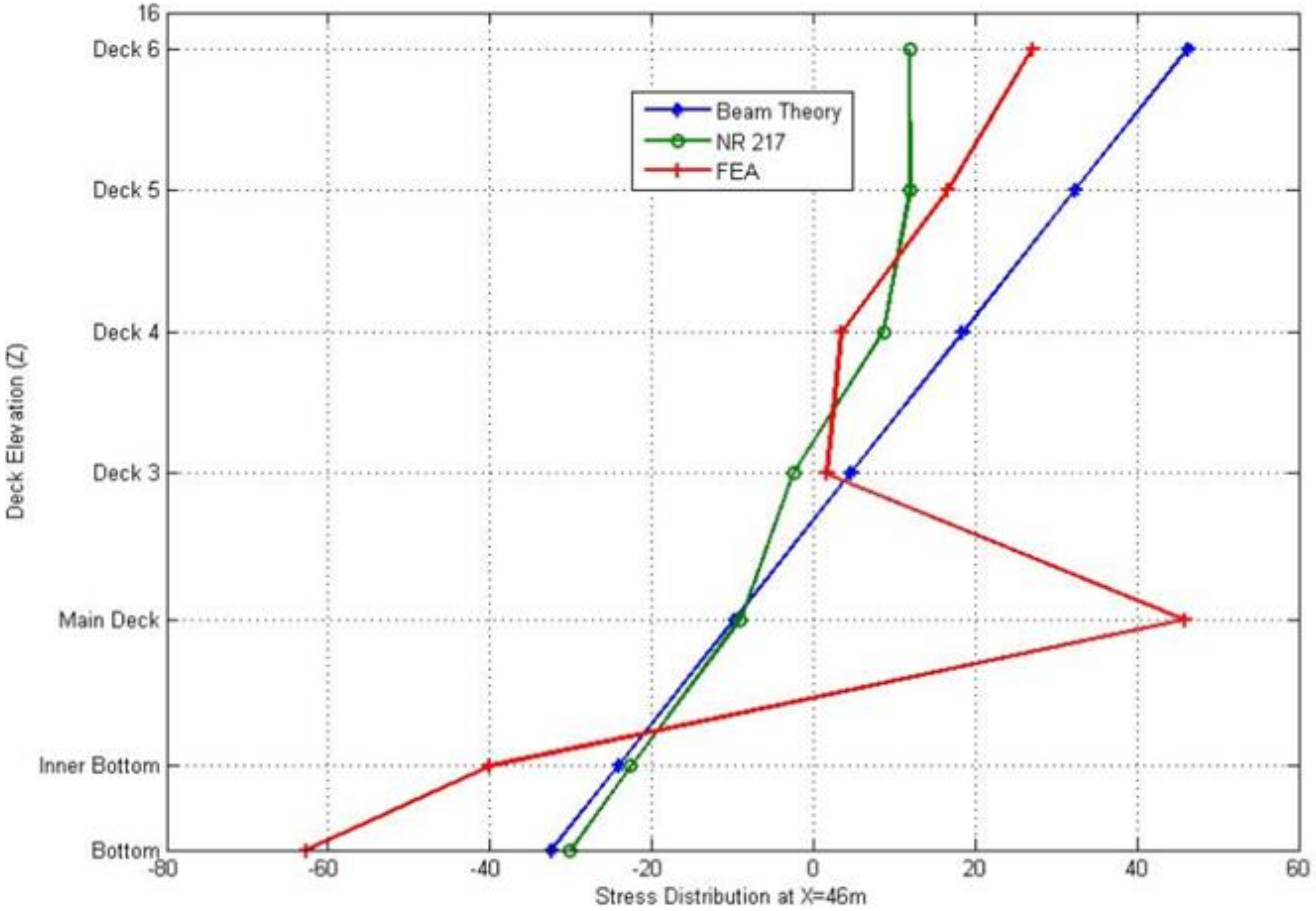
Analysis and Results

X=46m Results Comparison

Structural item	Z, [m]	Simple beam theory	NR 217		F.E.A
		σ_{x1}	□□v[%]□□ □	σ_{x2}	σ_{x3}
Bottom	0	-32.37	100	-30.04	-62.80
Inner Bottom	1.6	-24.14	100	-22.55	-40.71
Main Deck	4.4	-9.76	100	-9.06	45.85
Deck 3	7.2	4.63	56.69	2.44	1.73
Deck 4	9.9	18.50	50.41	8.66	3.53
Deck 5	12.6	32.38	39.98	12.01	16.66
Deck 6	15.3	46.25	27.71	11.89	27.06

Analysis and Results

X=46m Results Comparison



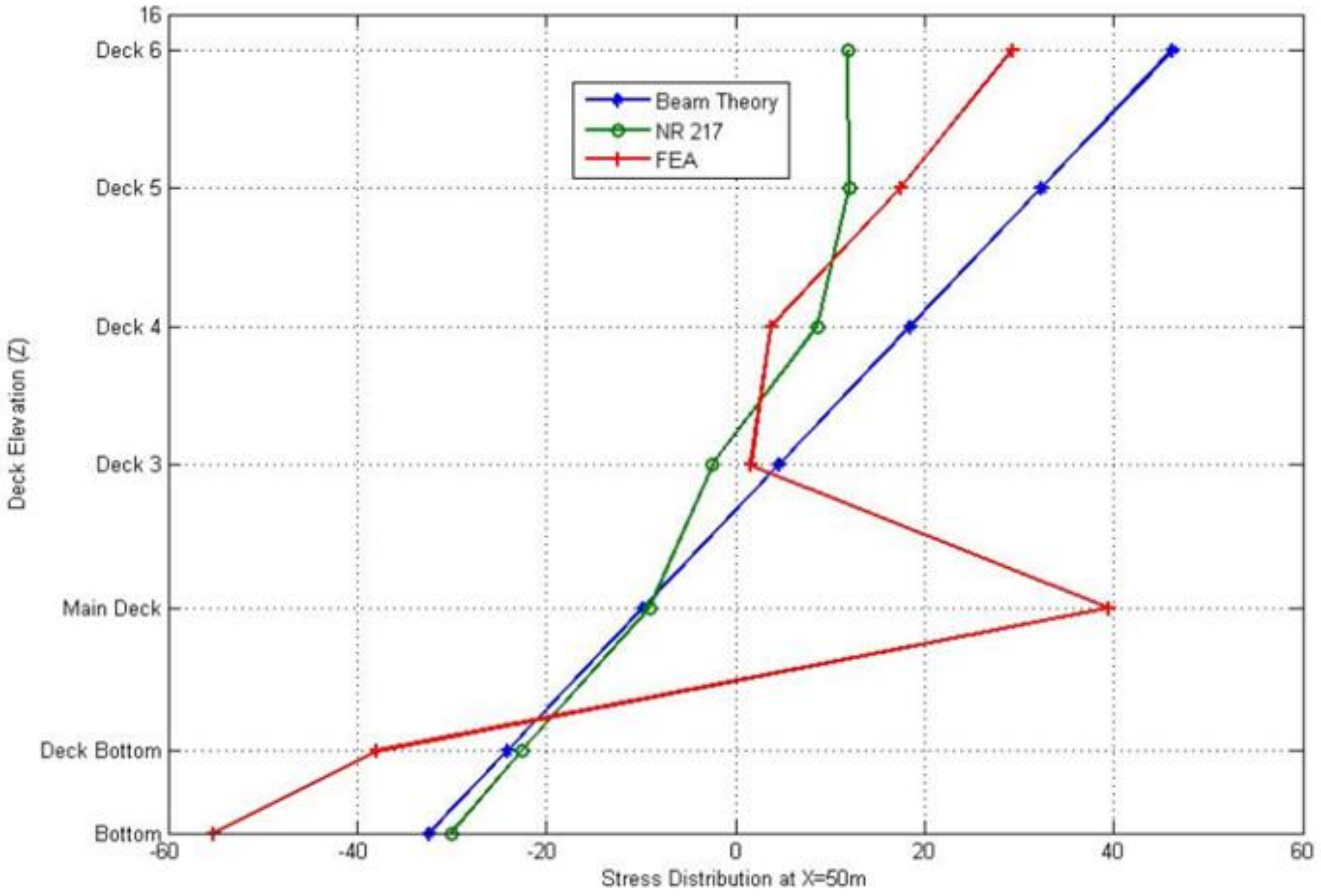
Analysis and Results

X=50m Results Comparison

Structural item	Z, [m]	Simple beam theory	NR 217		F.E.A
		σ_{x1}	□□v[%]□□ □	σ_{x2}	σ_{x3}
Bottom	0	-32.37	100	-30.04	-55.18
Inner Bottom	1.6	-24.14	100	-22.55	-37.96
Main Deck	4.4	-9.76	100	-9.06	39.46
Deck 3	7.2	4.63	56.69	2.44	1.68
Deck 4	9.9	18.50	50.41	8.66	3.77
Deck 5	12.6	32.38	39.98	12.01	17.44
Deck 6	15.3	46.25	27.71	11.89	29.25

Analysis and Results

X=50m Results Comparison



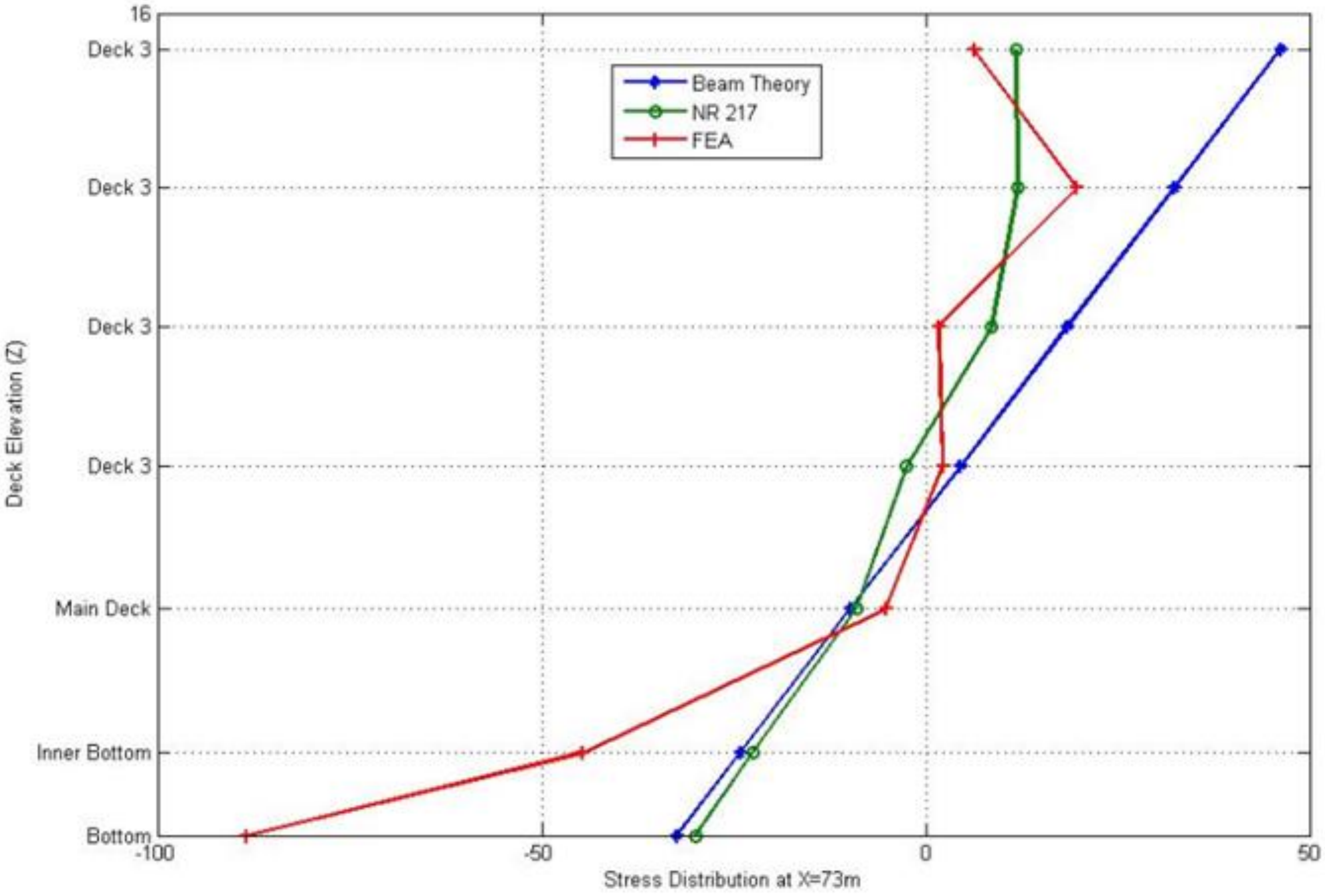
Analysis and Results

X=73m Results Comparison

Structural item	Z, [m]	Simple beam theory	NR 217		F.E.A
		σ_{x1}	□□v[%]□□ □	σ_{x2}	σ_{x3}
Bottom	0	-32.37	100	-30.04	-88.40
Inner Bottom	1.6	-24.14	100	-22.55	-44.69
Main Deck	4.4	-9.76	100	-9.06	-5.24
Deck 3	7.2	4.63	56.69	2.44	2.26
Deck 4	9.9	18.50	50.41	8.66	1.74
Deck 5	12.6	32.38	39.98	12.01	19.73
Deck 6	15.3	46.25	27.71	11.89	6.31

Analysis and Results

X=73m Results Comparison



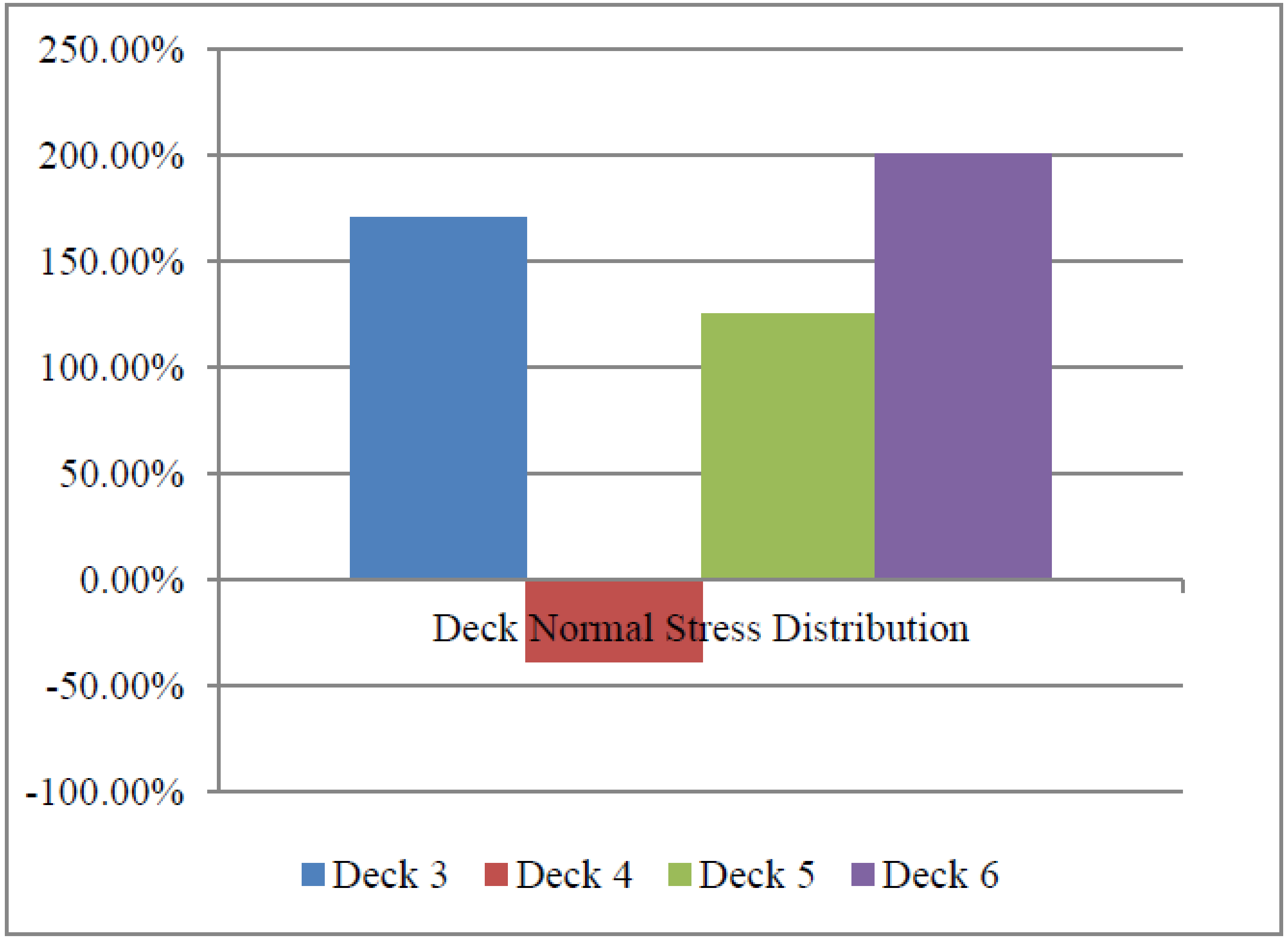
Conclusion

- Stress level of top decks and bottom and inner bottom in FEA is generaly higher than rule predicted values
- Longitudinal bulkheads are contributing to the hull girder strength and may cause local strength vairation, such as compression to tension, in the vicinal area
- Local structures will affect the hull girder normal stress
- Bending efficiency is generally increased at deck 6 and 5 about 30% whereas bending efficiency is reduced at deck 3 and 4 level about 30%

Bending Efficiency Change

	32m		37m		46m		50m		73m	
Bending Efficiency	RULE	FEA	RULE	FEA	RULE	FEA	RULE	FEA	RULE	FEA
deck3	56.69%	193.74%	56.69%	134.34%	56.69%	37.37%	56.69%	36.29%	56.69%	48.81%
deck4	50.41%	20.38%	50.41%	20.32%	50.41%	19.08%	50.41%	20.38%	50.41%	9.41%
deck5	39.98%	26.93%	39.98%	39.84%	39.98%	51.45%	39.98%	53.86%	39.98%	60.93%
deck6	27.71%	36.06%	27.71%	48.82%	27.71%	58.51%	27.71%	63.24%	27.71%	13.64%

Normal Stress Changes



Future Work

- Studies about the whole ship model
- Study the influence of side openings sizes on the strength of the ship
- Study deck by deck to see detail results compared with rules

Thank you for your attention