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DRY DOCK NO. 2 – FINITE ELEMENT ANALYSIS

Prepared for

BAE SYSTEMS
SAN FRANCISCO SHIP REPAIR

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Summary

BAE San Francisco Ship Repair Dry Dock No. 2 is an 800 ft. by 186 ft. by 69 ft. steel floating dry dock originally designed by Earl and Wright Consulting Engineers and built by Bethlehem Steel in 1969. The purpose of this strength analysis is to determine the safe dock lifting load based upon the current corrosion conditions. Doubler plating has been previously installed over much of the pontoon deck to help mitigate this problem. The last analysis of strength of the dock due to the corrosion effects was Elliott Bay Design Group's Finite Element Analysis (FEA) performed in 2008.

In June of 2012, two inspection teams performed Ultrasonic Testing (UT) measurements of the dock. The entirety of the bottom plating, pontoon deck, inboard wingwalls, outboard wingwalls, safety deck, and wingwall deck were measured in a 5 ft. by 5 ft. grid. A single transverse web frame and internal structure were measured at Frame 63. In this task, global and local Finite Element (FE) models were created based on the original Bethlehem Steel drawings of the drydock, and the thickness reductions based on the June 2012 UT measurements were applied. Stress analyses were performed to determine the maximum stresses in the dock based on the current rated capacity to lift a 56,690 LT ship. The new capacity of the dock specifically considers the wastage.

The primary stress pattern shown by the analyses is that of transverse bending of the dry dock. This is due to the load of the ship being primarily carried through the keel blocks along the centerline of the dock, while the water pressure on the underside of the dock acts uniformly upward. This results in a significant transverse sagging moment in the dock. Longitudinal bending of the dock is smaller in comparison and is controlled by the dockmaster by monitoring and controlling the longitudinal deformation of the dock by varying the water levels of individual ballast tanks to minimize the longitudinal bending moment. Vertical deflections in the dock due to the longitudinal stresses are monitored throughout the lifting operation and kept to within a maximum of three (3) inches. However, there is no active way to mitigate the transverse bending of the dock throughout the lifting operation. Note that maximum transverse bending stresses occur in transverse web frames and bulkheads that are fabricated of ordinary steel whereas when combined with longitudinal bending stresses, the maximum stress occurs in shell plating that is higher strength steel. It is prudent to continue monitoring and controlling the

vertical deflection of the dock from tank loading to within a maximum of three (3) inches, as this minimizes biaxial stresses that occur in the shell plating.

Results

The dock is constructed of A-36 steel with swaths of Mayari-R steel in key areas. A-36 steel is ordinary steel with a yield strength of 36,000 psi. Mayari-R steel is a higher strength steel with a yield strength of 50,000 psi. The original calculations assumed allowable stresses of 60% of yield, respectively. When performing FEA, it is realistic to assume a higher allowable stress depending on mesh size. This analysis is based on an allowable stress of 80% of yield.

The maximum stress in the dry dock when lifting a 56,690 LT ship is 47,816 psi in the Mayari-R steel in the bottom plating, which is greater than the allowable stress of 40,000 psi. The maximum stress in the A-36 steel is 39,000 psi in the lower portion of the transverse web frames, just outboard of the 9’-0” OCL WT longitudinal bulkhead. This portion of the web frames is constructed of A-36 steel with an allowable stress of 28,800 psi and a yield stress of 36,000 psi. Based on the local analyses of the dock in way of each pair of ballast tanks, the maximum ship load that can be lifted along the entire 800 ft. length of the dock without exceeding the allowable stresses, except in hot spots, is determined to be 54,800 LT. Hot spots are allowed to see stresses between allowable and yield strength because the stresses quickly dissipate moving away from the element located in the hot spot.

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Method

Structural System of Drydock

A description of the structural system of the dock is taken from Earl and Wright's structural design report of the dock (Ref. 8) when it was originally built:

"Two 6 ft. deep plate girders support the keel blocks for the entire deck length. Transverse pontoon bulkheads spaced at 10 ft. centers carry the loads from these girders and the side block loads to the longitudinal bulkheads 9 ft. and 42 ft. off the centerline and to the wing wall sides 75 ft. and 93 ft. off the centerline. The longitudinal bulkheads 9 ft. off the centerline are watertight, thereby forming an 18 ft. x 20 ft. x 800 ft. buoyancy chamber. This is divided into four compartments, each 200 ft. long. The transverse pontoon bulkheads are watertight each 40 ft. The wing wall plating is supported by trusses spaced at 10 ft. centers and by watertight bulkheads which match the pontoon watertight bulkhead spacing of 40 ft.

At the top of each wing wall, four buoyancy chambers 18 ft. x 7.5 ft. x 200 ft. are formed between the safety deck and the wing wall deck. The upper part of each wing wall is stiffened to support a 60 ton gantry crane."

Finite Element Models

Two separate finite element models were developed to analyze the strength of the dry dock: a global model and a local model. The global model consists of the entirety of the dry dock and is used to analyze the global longitudinal and transverse stresses in the dock. The local model consists of a full-beam portion of the dock that is truncated to 10% of the dock length. The local model is used to focus on the transverse bending of the dock, local plate stresses, hot spots, and buckling. The local model has a medium-size mesh that is finer than the mesh size used for the global model, but the local model's mesh is still relatively coarse. Because transverse bending of the dry dock was found to be more critical than longitudinal bending, this local model is very important in evaluating the strength of the dry dock, and because the dry dock has a very uniform structural arrangement along its length, the local model is applicable most anywhere along the length of the dock.

Software

The dry dock was modeled in FEMAP Version 10.3.1, copyright © 2012 Siemens Product Lifecycle Management Software, Inc. The solver is NEiNastran Version 10.1.0.410, published by NEi Software of Westminster, CA.

Material

Table 1 lists the two steels used in the construction of BAE SF Dry Dock No. 2 and examined in this analysis.

Table 1 – Steels in Model of BAE SF Dry Dock No. 2

Specification	Ultimate Stress psi	Yield Stress psi	Allowable Stress psi	Portions of Dry Dock
Mayari-R, ASTM A242	67,000	50,000	40,000	• Transverse WT Bhd and Transverse NT Web Frames – Rectangular Portion Bounded between 9'-0" to 42'-0" OCL, and Pontoon Deck down to 6'-8" below Pontoon Deck • Entirety of Original Pontoon Deck Plating • Bottom Plating Inboard of 51'-0"
ASTM A36	58,000	36,000	28,800	All non-Mayari-R steel, including the Pontoon Deck doubler plate

All steel is modeled with a Modulus of Elasticity (E) of 29,000,000 psi, a Poisson's Ratio (ν) of 0.32, and a density (ρ) of 7.33 x 10^{-4} lbf-s^2/in^4. Appendix A lists all of the element properties in the model.

Allowable Stress

In the original design of the dry dock, the allowable stress was specified to be 60% of the yield stress of the material. This 60% allowable stress was based upon stresses determined from hand calculations of simplified beam sections. However, in using FEA, we are considering the entire three-dimensional grillage structure of the dock simultaneously, and the results incorporate bending and stresses not only in the primary members, but also in secondary members as well. FEA is determining stresses much more thoroughly and accurately than the hand calculations of

40+ years ago. Therefore, we can safely increase the allowable stress from 60% to 80% of the yield strength of the material. Fatigue damage is not a concern with the dry dock as the number of high stress cycles is low (one cycle per ship docking) compared to the number of stress cycles of a seagoing ship in waves.

In some cases where elements are much smaller in size than the surrounding mesh in order to accommodate plate discontinuities or other very local details, the stresses in the local elements may be hot spots that do not accurately reflect the stresses in the area. In these cases, reported stresses will be those of the elements surrounding the hot spots.

The stresses of concern in this analysis are von Mises stresses, which arise from distortion energy theory. The use of von Mises stresses is quite accurate in predicting failure of steel parts. Von Mises stresses shown throughout the report indicate the maximum surface stresses on both sides of the plate members. The von Mises stress is defined as:

$$\sigma' = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2}$$

Where σ_1 and σ_2 are the principal stresses.

Lightship Weight Calculation

The lightship weight was estimated to be 19,268 LT based on the Elliott Bay Design Group Weight Report 08003-001-843-4B (Ref. 2) and discussion with A. Romanczuk on Aug. 23, 2012. Weights added to the lightship weight from the EDBG report include:

- Removal of temporary crane
- Addition of new East crane
- Two new transformers on Safety Deck
- Six sponsons (the EBDG lightship weight estimate specifically excluded the sponsons)
- Additional doubler plate on Pontoon Deck
- Accumulation of residual mud throughout the tanks

The lightship weight calculation is detailed in Appendix B. The only mass in the model is defined by the volume of the elements and their corresponding density. Because other dry dock masses besides the steel were not modeled, such as the cranes, dock blocks, residual mud in the ballast tanks, etc., the acceleration due to gravity in the model is modified so that the corresponding gravitational force on the dry dock steel in the model equals the lightship weight of the dry dock.

Global Finite Element Model

The global model consists of the entirety of the dry dock and is used to analyze the global longitudinal and transverse stresses in the dock.

Model Overview

The global FE model represents the full-length, full-beam dry dock, including the sponsons and fin recesses, but not including the truck ramp aprons on both ends. The global model consists of 326,280 elements and 255,658 nodes. All elements are modeled as plate elements, with the exception of the wingwall truss structure in the non-tight transverse frames modeled as beam elements, and the dock blocks modeled as rigid elements constrained in the vertical direction. The average mesh size of the plate elements is 10 ft. in the longitudinal direction to match the frame spacing and approximately 2.5 ft. in the transverse direction (varying to match the local stiffener spacing). See Figure 1 and Figure 2 showing the full model. Note the locations of the dock blocks.

A right-handed rectangular coordinate system is used throughout the modeling process. The origin is located at Frame 0, on Centerline, at the Baseline of the dock. The X-axis is oriented longitudinally with positive north from Frame 0, the Y-axis is oriented transversely with positive west from CL, and the Z-axis is oriented vertically with positive upward from baseline.

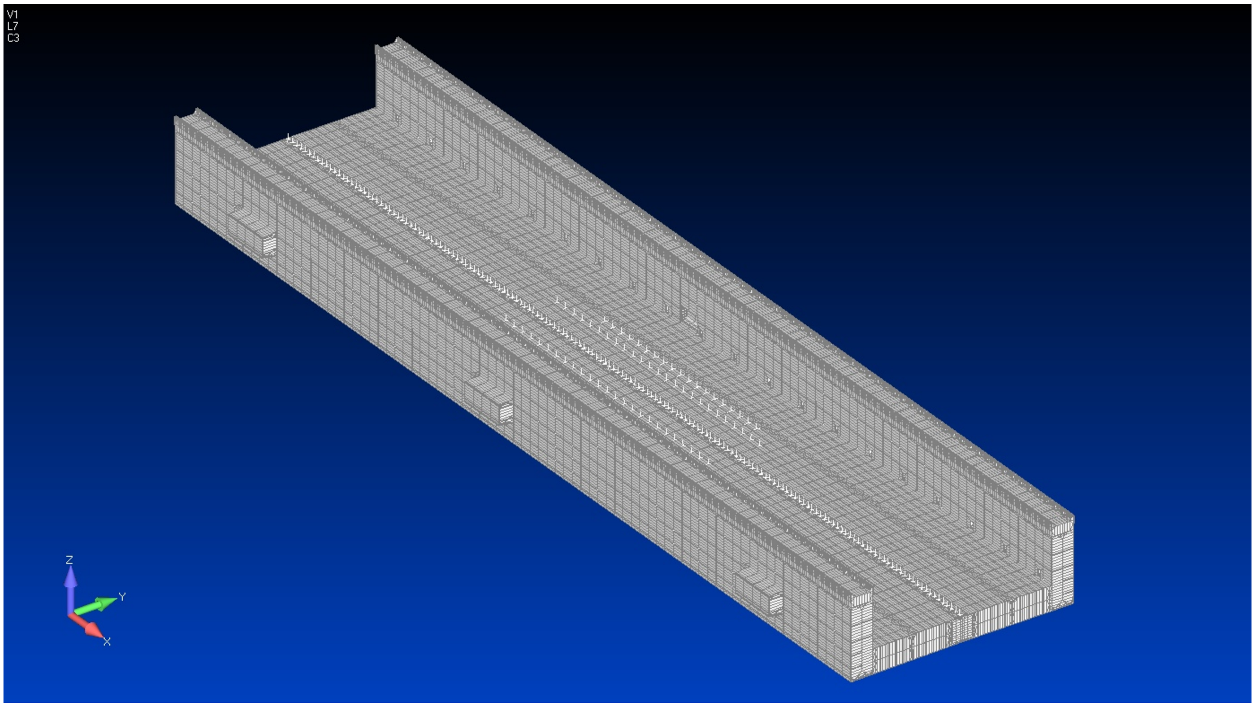

Figure 1 – Global FE Model of BAE Dry Dock No. 2

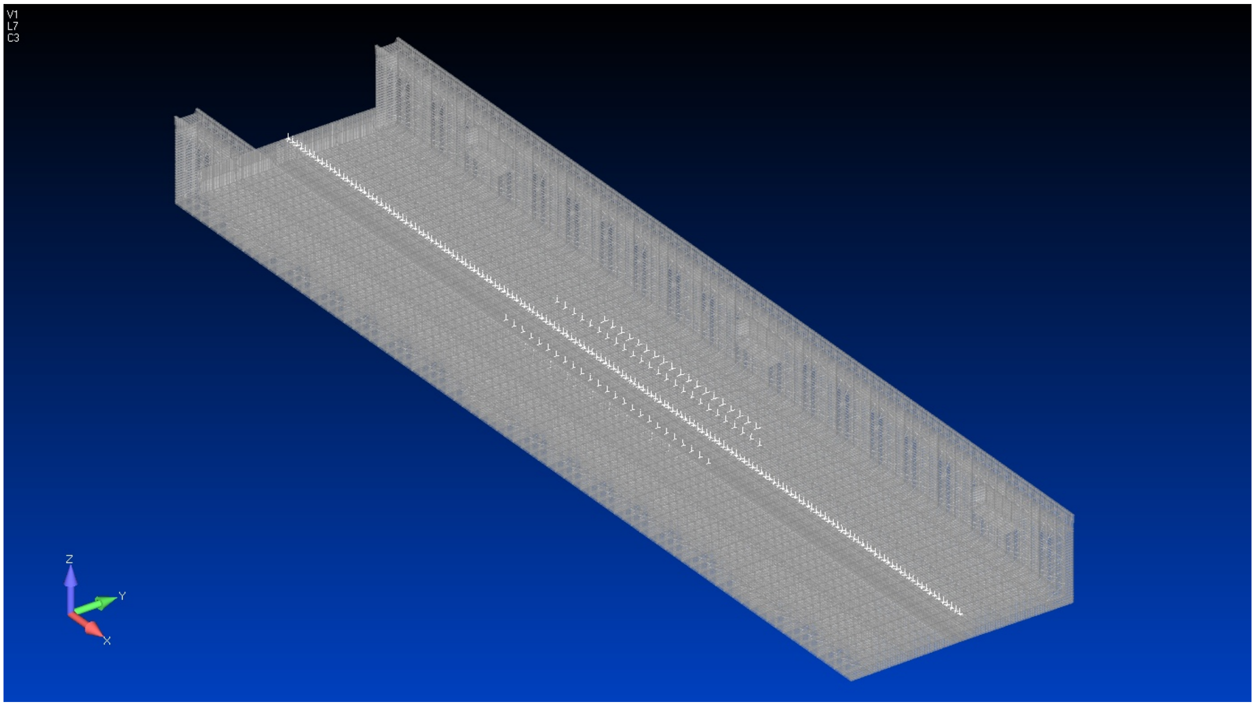

Figure 2 – Transparent View of Global FE Model

Corrosion Properties

The corrosion of the dry dock is modeled by categorizing the corrosion into various levels and then applying a uniform percentage thickness reduction to all elements within that corrosion level. Different colors of corrosion levels are shown in the model to facilitate identification. A 10% reduced thickness is applied in addition to the maximum allowed corrosion within each corrosion level to allow for some amount of future additional corrosion. This additional corrosion allowance is applied to all corrosion levels except for "unsatisfactory" and "extreme", as these corrosion levels already reduce the thickness from the original by at least 50%. Based on UT surveys of the dry dock in June of 2012, the corrosion of the dry dock was modeled with varying properties as follows:

- New/Renewed – Dark Green – Scantlings known to be in very good condition, such as the structure entirely inside the buoyancy compartment, are modeled with 15% reduced thickness.
- Satisfactory – Green – Scantlings with less than 15% corrosion are modeled with 25% reduced thickness.
- Marginal – Yellow – Scantlings with between 15% and 25% corrosion are modeled with 35% reduced thickness.
- Unsatisfactory – Red – Scantlings with between 35% and 50% corrosion are modeled with 50% reduced thickness.
- Extreme – Purple – Scantlings with greater than 50% corrosion are modeled with 75% reduced thickness.

This conservative method of accounting for the corrosion of the dock and allowing for future corrosion supports the use of the allowable stress of 80% of yield as previously mentioned. Figure 3 and Figure 4 show the corrosion properties as modeled, with colors to indicate the corrosion level. For the corrosion applied to the model on the Bottom Plating, Pontoon Deck, and Outboard Wingwalls, uniform thickness reductions were applied to swaths of plating indicating the general corrosion in that area, rather than updating the corrosion properties of each element in the model individually. For example, in an area of plating that is primarily shown as "Marginal," a 35% thickness reduction is applied to that entire region of plating uniformly, although there may be some locations of "Satisfactory" and "Unsatisfactory" thickness measurements in that region. Appendix C shows plots of the corrosion from the UT inspections, as well as plots of the corrosion properties applied to the model.

The internal frames and stiffeners were modeled with corroded properties based on a survey at Frame 63. These corrosion properties of the internal structure at Frame 63 were used as representative of the corrosion of the internal structure throughout the length of the dock. Most of the internal structure is less than 15% corroded.

The only existing structure in the dock modeled as "new/renewed", with only 15% reduced thickness, is the structure inside the buoyancy chamber. This does not include the boundary surfaces of the buoyancy chamber (Pontoon Deck, Bottom Plating, and WT Longitudinal Bulkheads 9'-0" OCL), which were modeled with corrosion per the UT inspection reports. Thickness measurements were not taken of the doubler plating on the Pontoon Deck. The Pontoon Deck in way of the doubler plating was modeled as a single 0.500 in. plate with 25% reduced thickness (therefore an effective thickness of 0.375 in.).

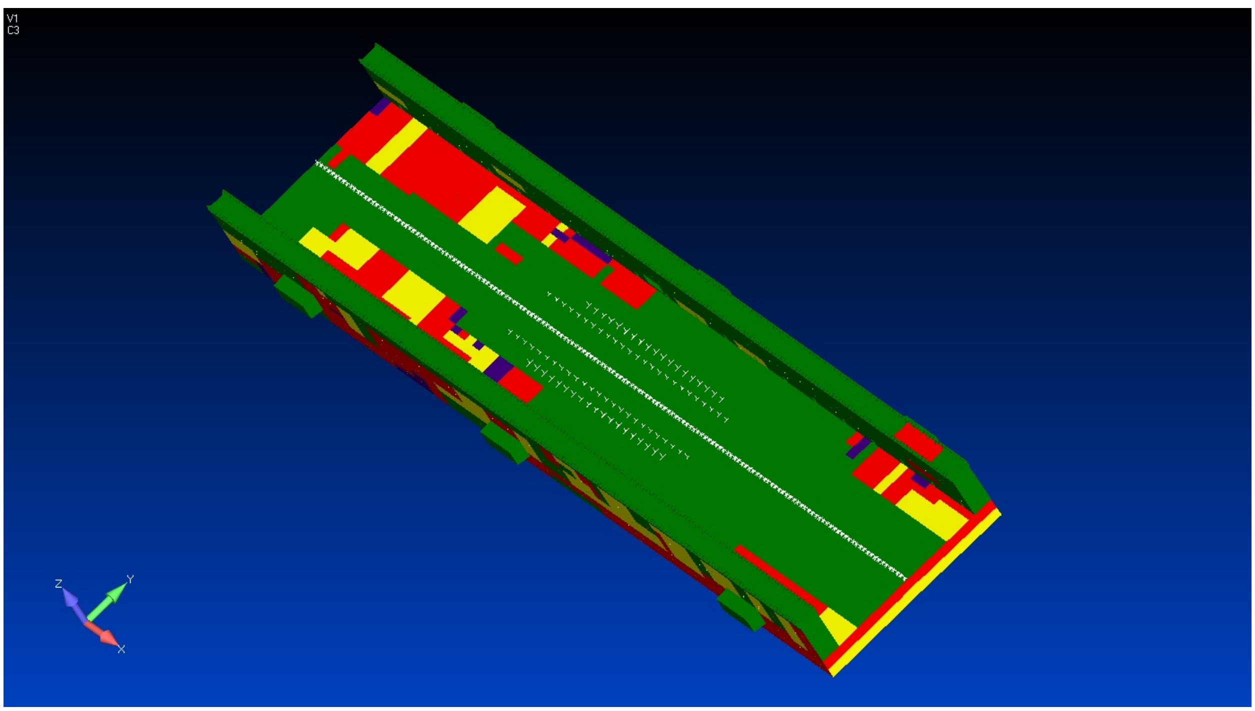

Figure 3 – Corrosion Properties Applied to Global Model – Top View

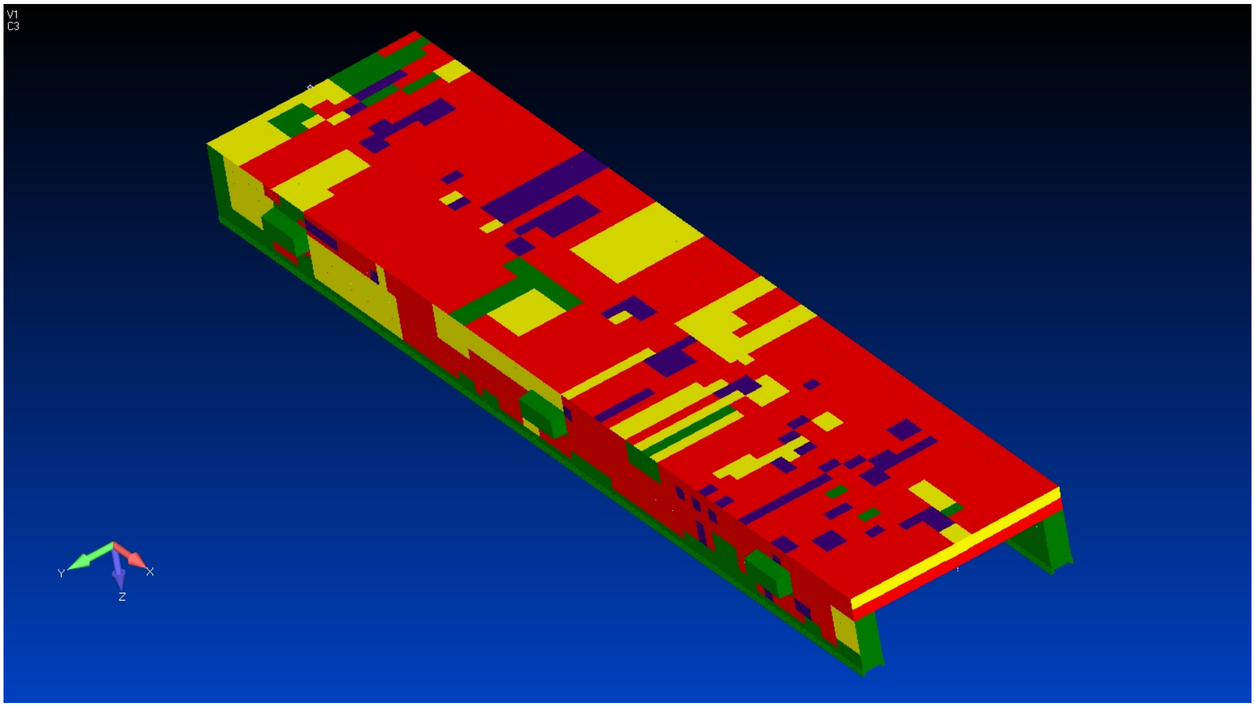

Figure 4 – Corrosion Properties Applied to Global Model – Underside View

Ship Load

The analysis was performed with the previously prescribed maximum allowable dry dock ship weight of 56,690 LT, with a weight distribution averaging approximately 71 LT/ft. and ranging from 65 LT/ft. to 73 LT/ft. Table 2 lists the longitudinal weight distribution of the 56,690 LT ship. Keel dock blocks extend the full length of the dry dock, while the side blocks are located from Frames 29 to 53. Where side blocks are located, the ship weight is assumed to be distributed with 70% of the weight on the keel blocks and the remaining 30% of the weight on the side blocks. Note that in order to lift a 56,690 LT ship, the dry dock must be competent in transverse bending for a keel block load of 73 LT/ft., the maximum ship weight listed in Table 2.

Table 2 – 56,690 LT Ship Load – Longitudinal Weight Distribution

Distance from South End	Ship Weight
ft.	LT/ft.
0 - 80	70
80 - 160	65
160 - 240	70
240 - 590	72
590 - 720	73
720 - 800	70

Loading Cases

Four (4) different load cases were analyzed with the global FE model, all based on the maximum ship weight of 56,690 LT. The dry dock lightship weight is included as a gravitational body load applied to the elements. The ship loads are applied as point loads, which are representative of the longitudinal weight distribution of the ship, to the rigid elements representing the dock blocks in the model. No other local loads were tested, such as vehicles driving on the dock, crane loads, or mooring loads. The analysis type performed for all four load cases is linear-static.

Instead of modeling the ship's weight distribution as point loads, the ship load could have been modeled as a continuous longitudinal weight distribution applied to beam elements that would incorporate the longitudinal stiffness interaction between the ship's longitudinal hull girder and the dry dock's longitudinal strength. However, as is shown later in the report in the section on global stresses, the longitudinal stresses in the dry dock are not of paramount concern, given that the longitudinal deflections are properly maintained during the docking cycle via ballasting. Therefore, the simplification of modeling the ship as point loads directly applied to the dock blocks is accurate.

The analyses test the following four load cases representing various stages in the docking cycle:

1. <u>Load Case 1</u>: This condition is based on the maximum design submergence of the dry dock (Stability Phase I). The dry dock is modeled at a draft of 55 ft., and the ballast tanks are modeled as being filled with 41.58 ft. of seawater. No ship load is applied in this load case.
2. <u>Load Case 2</u>: This condition is based on the maximum differential water pressure on the external boundaries of the dry dock (Stability Phase II). The dry dock is modeled at a draft of 46.75 ft., and the ballast tanks are modeled as being filled to 20 ft. (the level of the pontoon deck). A ship load of 13,360 LT is applied uniformly along the length of the dock as a distributed load of 16.7 LT/ft. This ship weight was determined based on the available buoyancy of the dry dock floating in equilibrium at this condition.

3. Load Case 3: This condition is based on the point of docking the ship where the draft of the dry dock is at the top of the keel blocks, and the entire weight of the ship is now bearing on the dock (Stability Phase III). The dry dock is modeled at a draft of 25.75 ft., and the entire ship load of 56,690 LT is applied. Ballast tanks are modeled as 4.11 ft. filled to achieve equilibrium.

4. Load Case 4: This condition is based on the final lifting phase of the dock at its corresponding minimum lifting draft. The dry dock is modeled at a draft of 18.24 ft., and the entire ship load of 56,690 LT is applied. Ballast tanks are modeled as empty. In reality, they can be stripped to approximately four (4) inches of remaining ballast.

The analyses show that Load Cases 3 and 4, with the maximum ship weight applied, are by far the dominant load cases. Load Case 3, with the dry dock draft of 25.75 ft., was shown to be slightly more demanding. The results of Load Case 3 for the global model are presented below; all four load cases are further analyzed in the local model. Table 3 lists the load cases tested in this analysis of the global model.

Table 3 – Global Model Load Cases

Load Case	Dock Draft ft.	Dock Ballast ft.	Dock Lightship LT	Ship Weight on Dock LT
1	55.00	41.58	19,268	0
2	46.75	20.00	19,268	13,360
3	25.75	4.11	19,268	56,690
4	18.24	0	19,268	56,690

Stress Analysis – Global Model – Load Case 3

The primary stress pattern shown by the analysis of the global model is that of transverse bending of the dry dock. This is due to the load of the ship being primarily carried through the keel blocks along the centerline of the dock, while the water pressure on the underside of the dock acts uniformly upward (see Figure 5). This results in a significant transverse sagging moment in the dock. Longitudinal bending of the dock is small in comparison and can be controlled throughout the docking operation by monitoring the vertical deformation of the dock and varying the water levels of individual ballast tanks to minimize longitudinal bending moments. However, there is no active way to mitigate the transverse bending of the dock throughout the lifting operation, other than what naturally exists through the transfer of loading into the side blocks, where present.

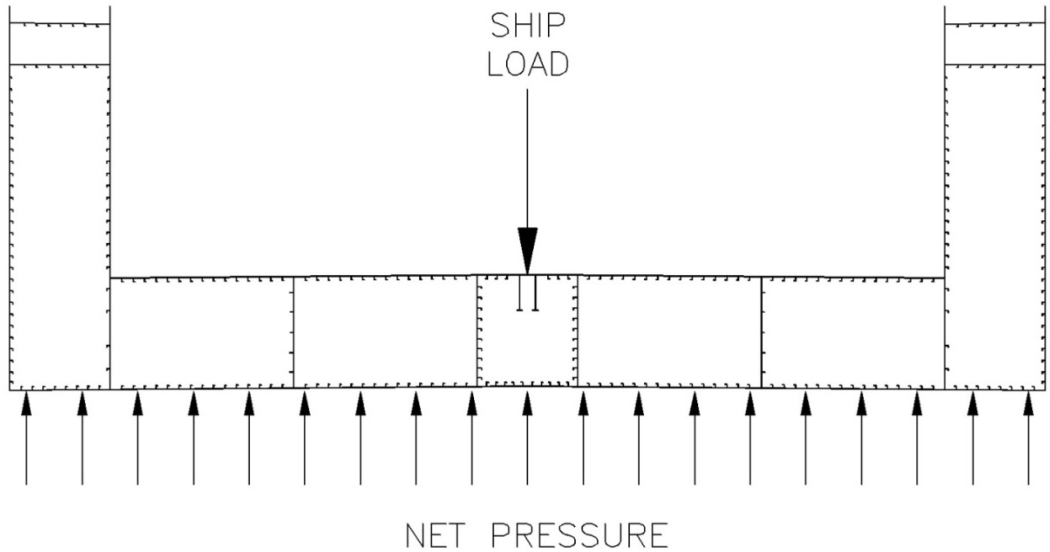

Figure 5 – Concentrated Ship Load Inducing Transverse Sagging Moment in Dock

The primary members of concern are the bottom portions of the transverse frames and the bottom plating, as these elements are under the maximum tension due to the transverse sagging of the dock. Stresses are highest near centerline and decrease going outboard. The stresses in the stiffeners were shown to be relatively small in comparison to the transverse frames and the deck plating.

All stress plots shown in this report are von Mises stress plots. In the following von Mises stress plots, orange and red represent the highest stresses, while violet and blue represent the minimum stresses. Any red elements exceed the allowable stress criteria. All of the plots are shown as “undeformed.”

Bottom Plate

Figure 6 shows the stresses in the Mayari-R portion of the bottom plating with an allowable stress of 40,000 psi. There are some hot spot areas with high stresses in locations of “unsatisfactory” and “extreme” corrosion in the bottom plate. The maximum stress in the Mayari-R portion of the bottom plate is 38,997 psi, which is less than the allowable stress.

The bottom plate outboard of 51’-0” is A-36 steel with a 28,800 psi allowable stress. This portion of the bottom plate has significantly lower stresses than the elements near centerline and is well below the allowable stress (see Figure 7). The maximum stress in the A-36 portion of the bottom plate is 9,191 psi, which is well below the allowable stress. The bottom plating and associated stiffeners are examined again in more detail in the local model.

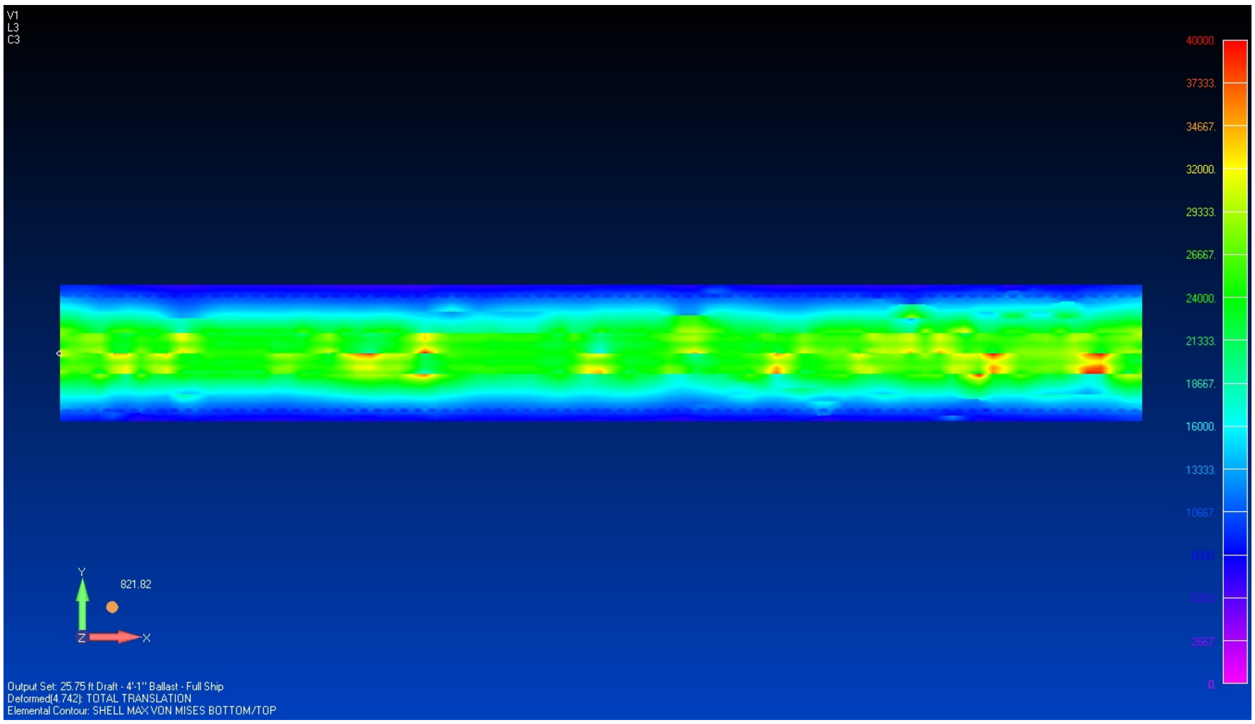

Figure 6 – Load Case 3 – Bottom Plate – Mayari-R – 40,000 psi Allowable

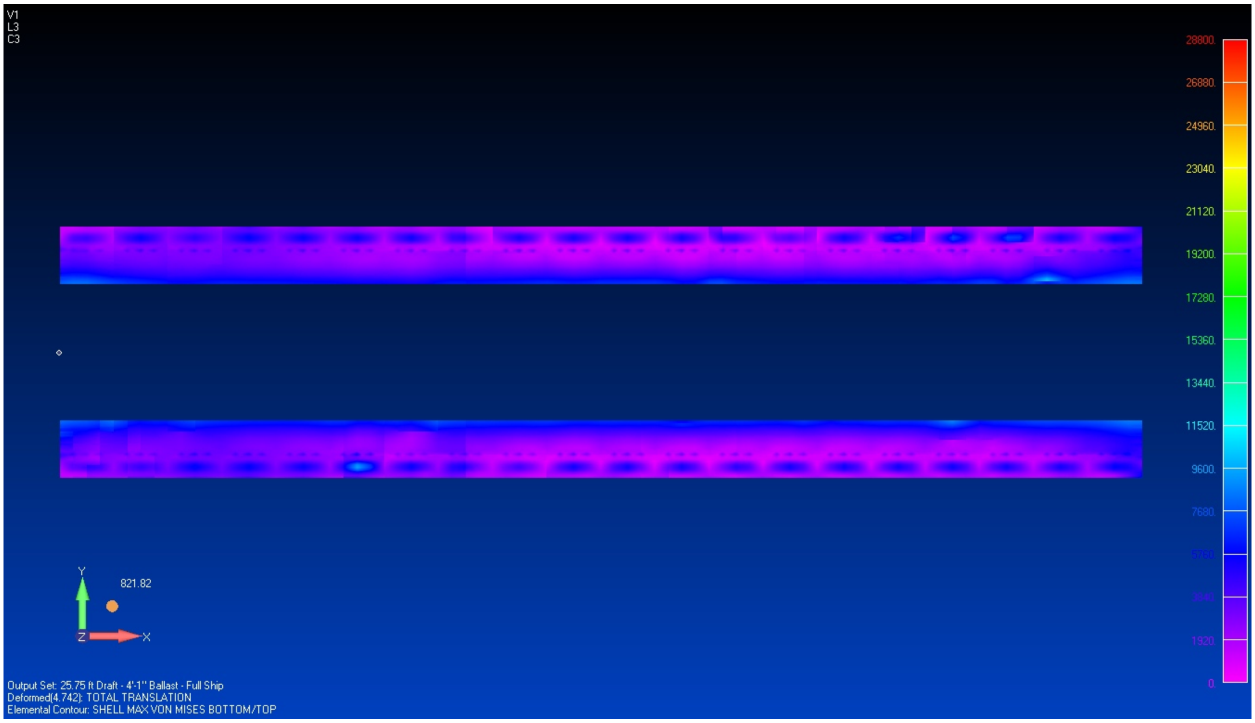

Figure 7 – Load Case 3 – Bottom Plate – A-36 Steel – 28,800 psi Allowable

Pontoon Deck

The entirety of the original Pontoon Deck steel is Mayari-R steel, while the Pontoon Deck doubler plate is A-36 steel. We are more concerned with the original deck plating, rather than the doubler plate, which is in relatively good condition compared with the original plating. Figure 8 shows the original portion of the Mayari-R Pontoon Deck plating with an allowable stress of 40,000 psi. The maximum stress in the Mayari-R portion of the Pontoon Deck is 32,660 psi, which is below the allowable stress.

Figure 9 shows the A-36 doubler plate portion of the Pontoon Deck plating with an allowable stress of 28,800 psi. The maximum stress in the A-36 portion of the Pontoon Deck is 32,076 psi, which is above the allowable stress. The Pontoon Deck and associated stiffeners are examined again in more detail in the local model.

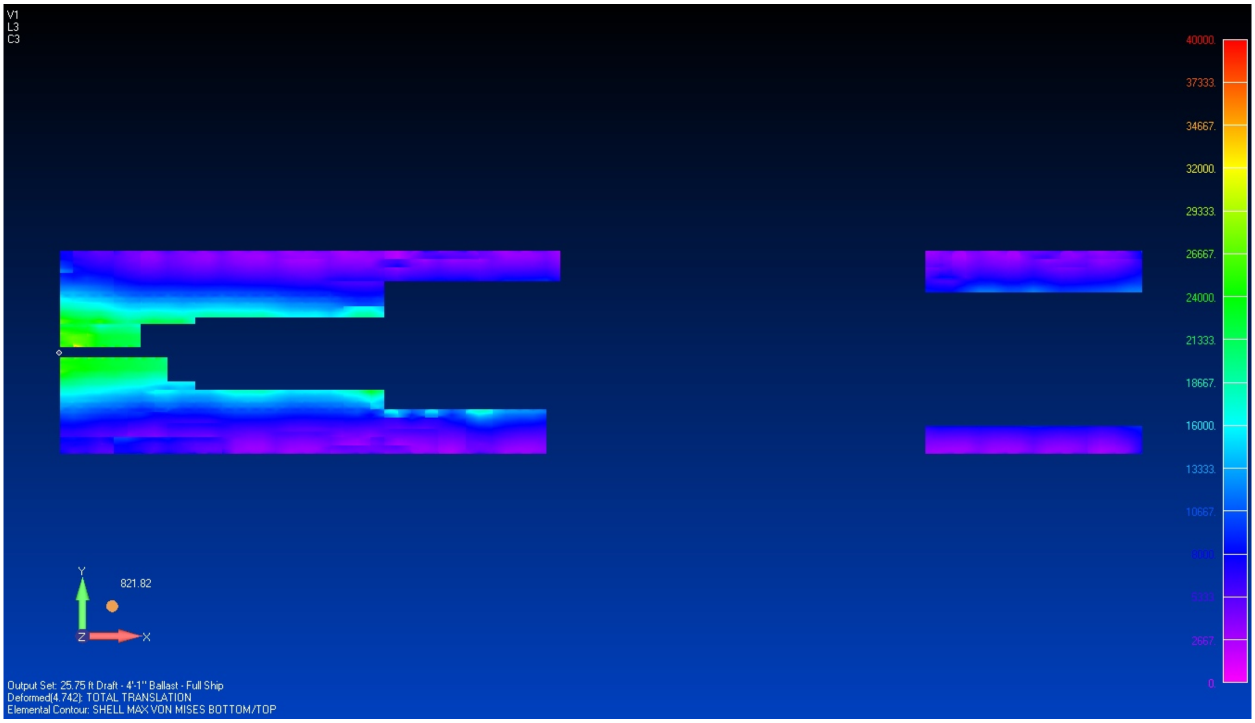

Figure 8 – Load Case 3 – Original Pontoon Deck Plate – Mayari-R – 40,000 psi Allowable

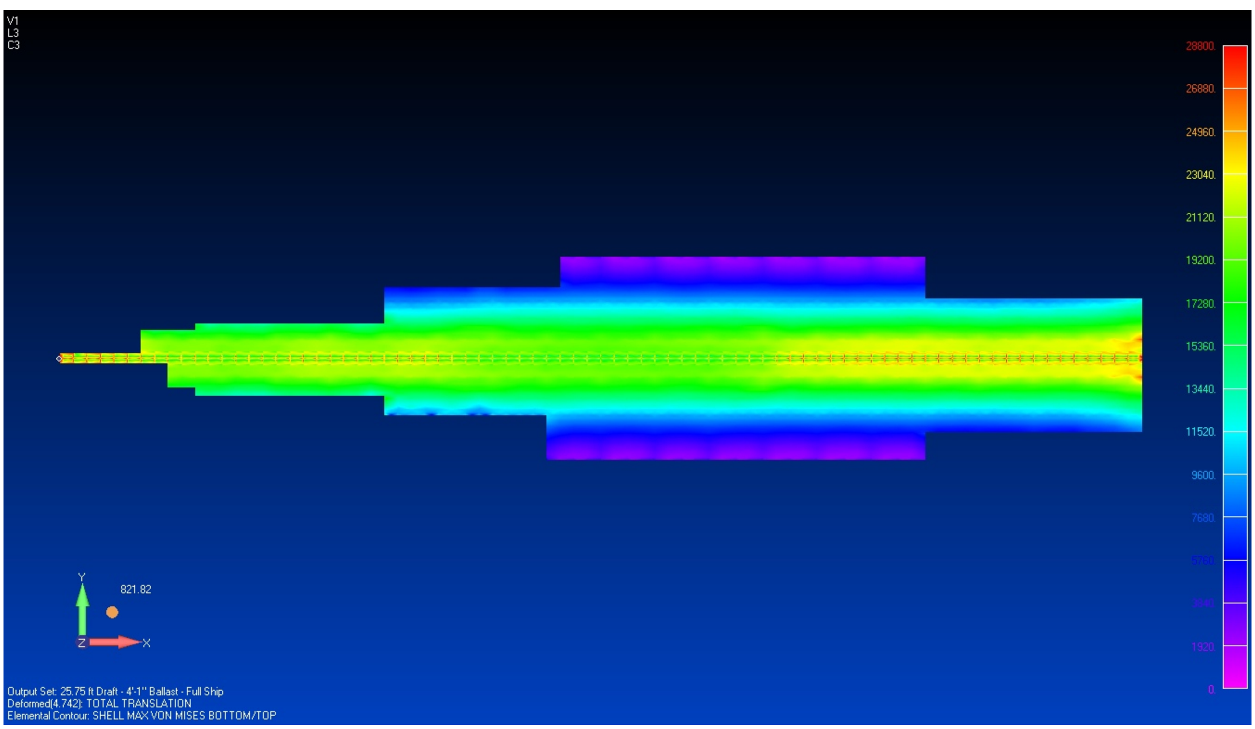

Figure 9 – Load Case 3 – Doubler Pontoon Deck Plate – A-36 Steel – 28,800 psi Allowable

Transverse Frames

Figure 10 and Figure 11 show the von Mises stresses in typical NT web frames. Stress levels and patterns in the WT web frames are very similar. The upper 1/3 of the frames between the 9’-0” and 42’-0” OCL longitudinal bulkheads are Mayari-R steel, and the rest of the frames are A-36 steel. Figure 10 shows the A-36 portions of the NT web frames with the allowable stress of 28,800 psi, and Figure 11 shows the Mayari-R portions of the NT web frames with the allowable stress of 40,000 psi. The maximum stress in the A-36 portions of the web frames is 39,001 psi, which is greater than the allowable stress of 28,800 psi. The maximum stress in the Mayari-R portions of the web frames is 32,754 psi, which is less than the allowable stress of 40,000 psi.

Notice that the upper portion of the frames, which is constructed of Mayari-R steel with the higher allowable stress, shows lower overall stresses than the lower portion of the frames. Also note that the transverse frames are modeled as “new/renewed” with 15% reduced thickness inside the buoyancy compartment (inboard of 9’-0” OCL), and the transverse frames outboard of 9’-0” OCL are modeled as “satisfactory” with 25% reduced thickness.

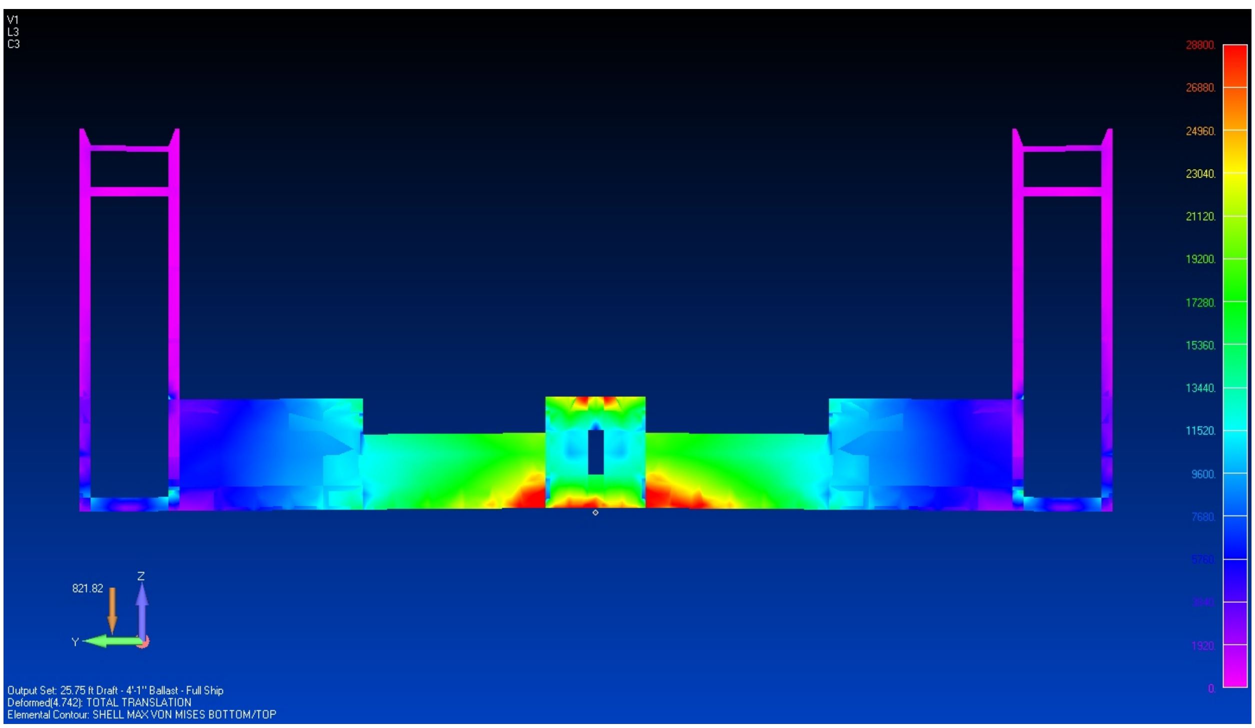

Figure 10 – Load Case 3 – Typical NT Web Frame – A-36 Steel – 28,800 psi Allowable

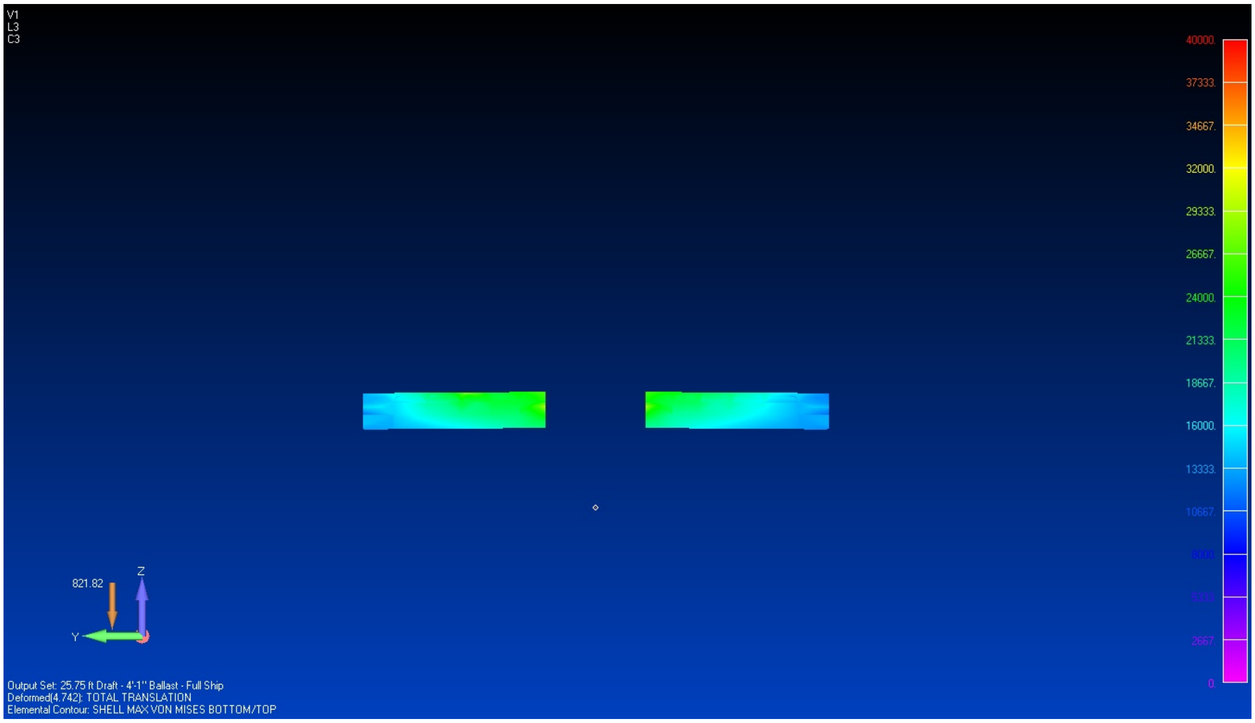

Figure 11 – Load Case 3 – in Typical NT Web Frame – Mayari-R – 40,000 psi Allowable

As is evident by the figures above, there are portions of the dry dock with greater than allowable stresses when lifting a 56,690 LT ship. The analysis is continued by next analyzing the local model. The maximum ship load that can be lifted without exceeding the allowable stresses is then determined with an additional allowance for hot spots.

Local Finite Element Model

The local model is used to focus on the transverse bending of the dock, local plate stresses, hot spots, and buckling. The local model has a medium-size mesh that is finer than the mesh size used for the global model, but the local model's mesh is still relatively coarse. Areas of concern from the global model, such as the lower portions of the web frames, are investigated further. Due to the smaller mesh size, the results from the local model are more accurate than those from the global model.

Model Overview

The local FE model represents an 80 ft. long section of the dry dock from Frame 18 to 26. The local model is full-beam and full-depth. The section from Frame 18 to 26 was chosen for further analysis for numerous reasons:

1. In a typical docking condition, there are no side blocks, only keel blocks, in this location.
2. The pontoon deck doubler plate is less used in this section than farther aft.
3. There are no sponsons, fin recesses, or other unusual appendages in this area that would add extra strength and/or stress risers. (Note: No high stress areas of concern were found in the global model in way of the appendages.)
4. Corrosion is quite extensive on the pontoon deck and bottom plate in this area.

The local model is intended to analyze a section that is one tank spacing long with a one-half tank length on both ends to provide accurate stiffness at the tank ends and to reduce the effects of boundary constraints in the transverse WT tank bulkheads.

The local model consists of 82,594 elements and 75,898 nodes. All elements are modeled as plate elements, with the exception of the wingwall truss structure in the non-tight transverse frames modeled as beam elements, and the dock blocks modeled as rigid elements constrained in the vertical direction. The average mesh size of the plate elements is 2.5 ft. in the longitudinal direction to have four elements per frame spacing and approximately 2.5 ft. in the transverse direction (varying to match the local stiffener spacing, or one element per longitudinal frame). See Figure 12 and Figure 13 showing the local model. The same origin and coordinate system from the global model are used for the local model.

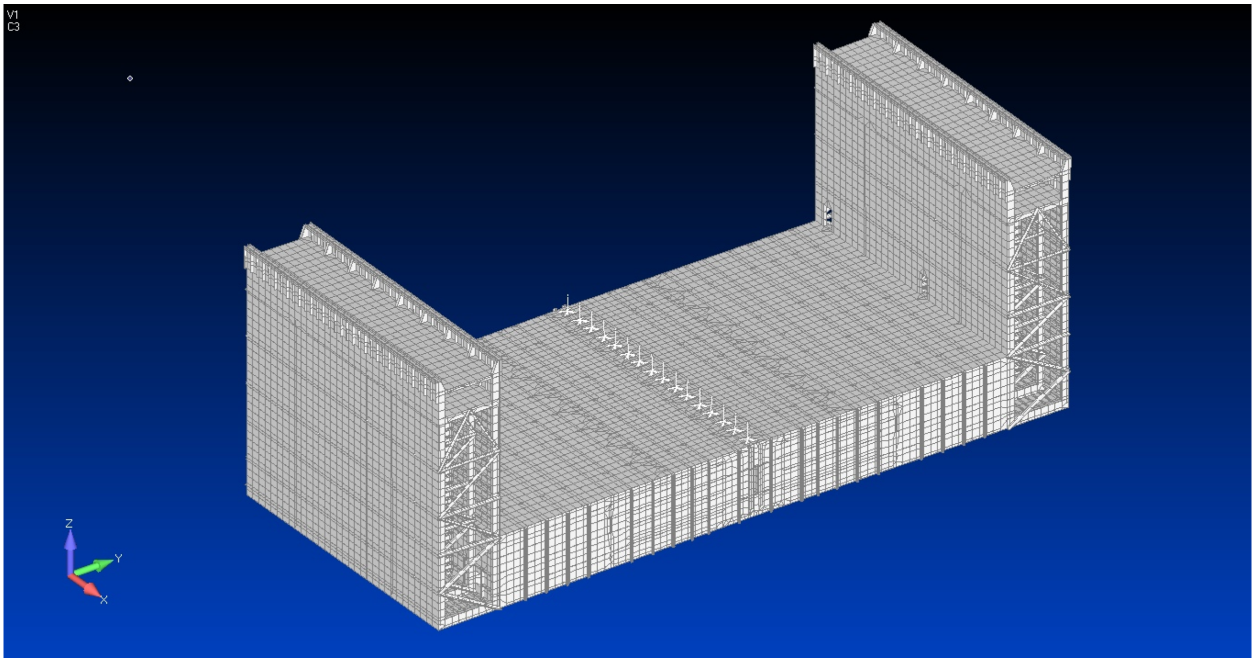

Figure 12 – Local FE Model of BAE Dry Dock No. 2

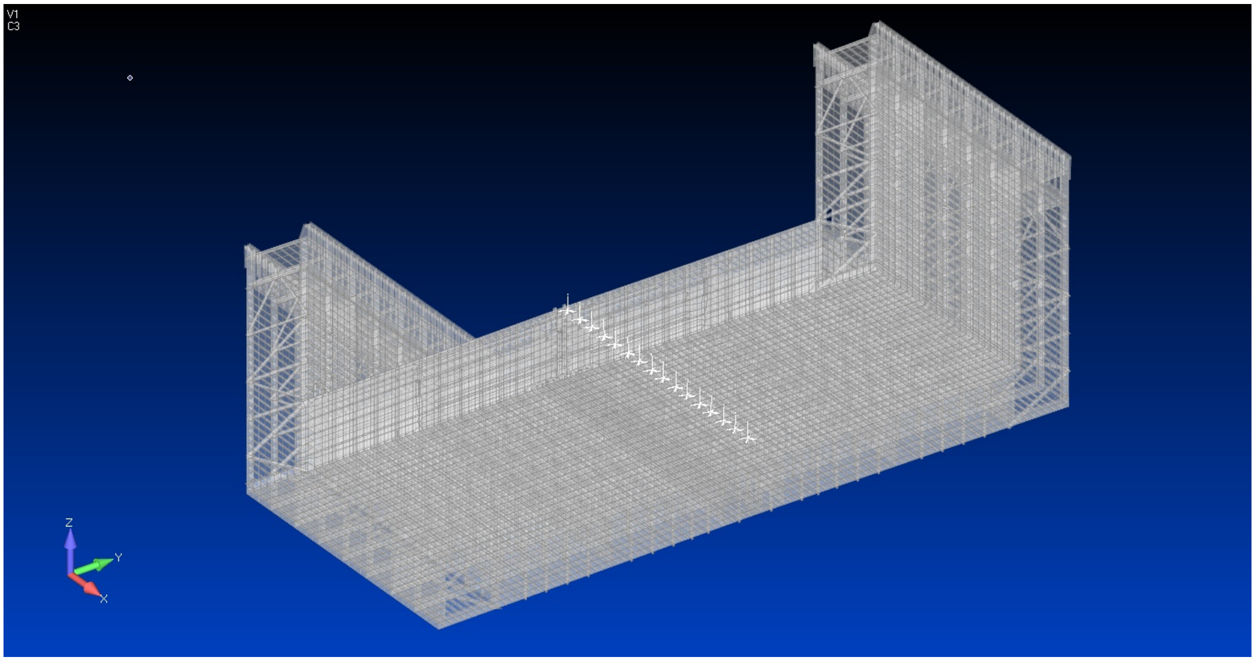

Figure 13 – Transparent View of Local FE Model

Corrosion Properties

The same corrosion level categories from the global model are used for the local model. The thickness reductions applied to the local model are in 5 ft. by 5 ft. grids to use the full accuracy of the thickness measurements taken on the dry dock. Figure 14 and Figure 15 show the corrosion properties as modeled, with dark green representing "new/renewed", with green representing "satisfactory", yellow representing "marginal", red representing "unsatisfactory", and purple representing "extreme", as before with the global model.

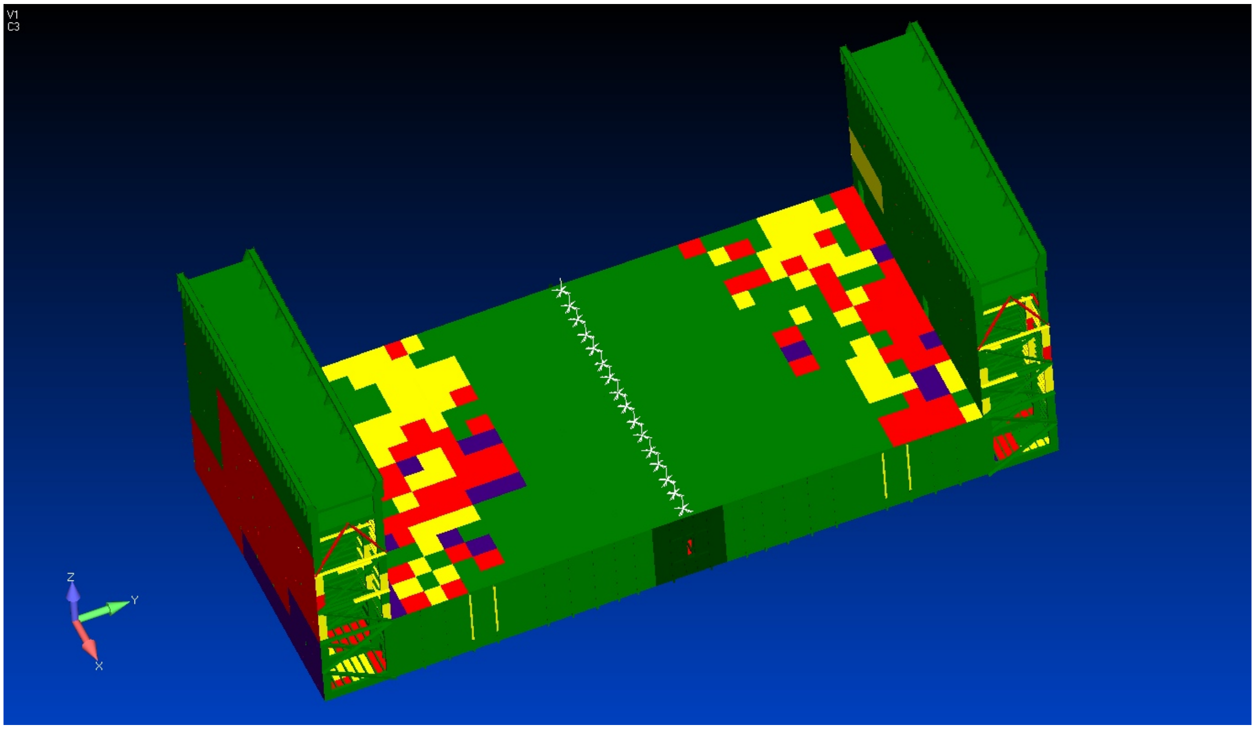

Figure 14 – Corrosion Properties Applied to Local Model – Top View

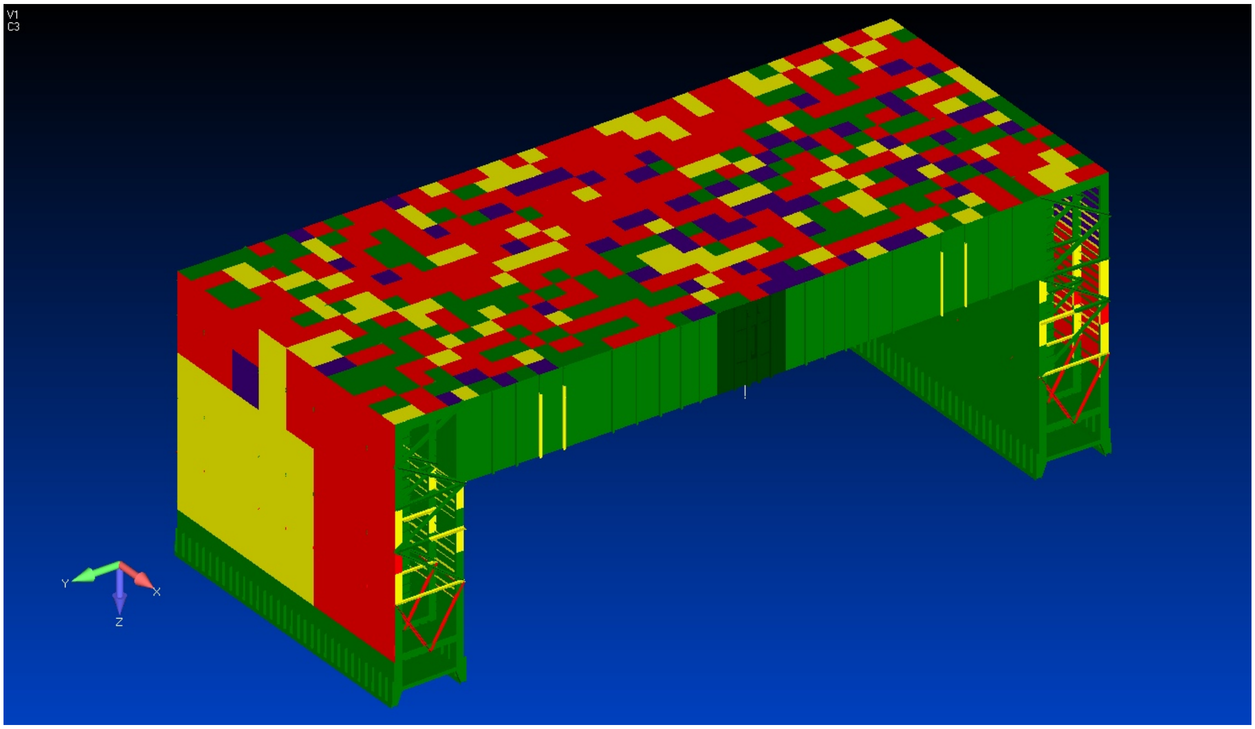

Figure 15 – Corrosion Properties Applied to Local Model – Underside View

Ship Load

The ship loads in the local model are applied as a constant ship longitudinal weight distribution. In this situation, the maximum weight per length in the previously prescribed distribution is 73 LT/ft. Therefore, a 73 LT/ft. load is applied along the length of the 80 ft. long dock section.

Loading Cases

The same four (4) different load cases from the global model were analyzed with the local model. However, in the case of the local model, the ship weight was applied simply as a weight per length because only a section of the dock is being analyzed. Table 4 lists the load cases tested in this analysis of the global model. In later iterations where the maximum lifting capacity of the dock is determined, while staying below the allowable stress, the ship's weight per length is modified and noted. For these iterations, the dock draft and ballast levels are modified accordingly to achieve equilibrium in the corresponding condition.

Table 4 – Local Model Load Cases

Load Case	Dock Draft ft.	Dock Ballast ft.	Dock Lightship per 80 ft. LT	Ship Weight on Dock LT/ft.
1	55.00	41.58	1,927	0
2	46.75	20.00	1,927	15.33
3	25.75	3.48	1,927	73
4	18.65	0	1,927	73

Stress Analysis – Dock in Original Condition – Load Case 4

As a test of the validity of the FE model, the dock was analyzed with all plating in the as-built condition of the dock. This helps to validate the model by comparing the stress results to the original design stresses of the dock, and it serves to identify any trouble areas that have been present since the dock was originally built.

Analyzing the original dock with the 73 LT/ft. load in the local model identified that the lower portion of the web frames is still the highest stressed area in the dock, with stresses of approximately 19,000 psi. The original dock calculations used a ship load of 84 LT/ft. for the transverse bending condition. Linearly extrapolating the 19,000 psi stress based on a 73 LT/ft. ship to 84 LT/ft. results in stresses of approximately 21,900 psi. This compares very closely to the original hand calculations for the dock from Earl and Wright, which calculated the maximum transverse bending stresses to be 21,800 psi. This both confirms that the hand calculations from 1969 were accurate and that the FE model is accurately calibrated to model the transverse bending stresses.

Stress Analysis – Load Case 1

Load Case 1 represents the maximum submergence of the dry dock to a 55 ft. draft, ballasted to reach equilibrium. There is no ship load in this case. The maximum stress in the model is 19,149 psi. Maximum stresses are found in the outboard web frame structure and the bottom plate stiffeners in way of the buoyancy chamber. The maximum beam stress in wingwall truss structure is 13,852 psi. These stresses are less than the allowable stress of 28,800 psi and are acceptable. Figure 16, Figure 17, and Figure 18 show the stress plots for Load Case 1 based on an allowable stress of 28,800 psi.

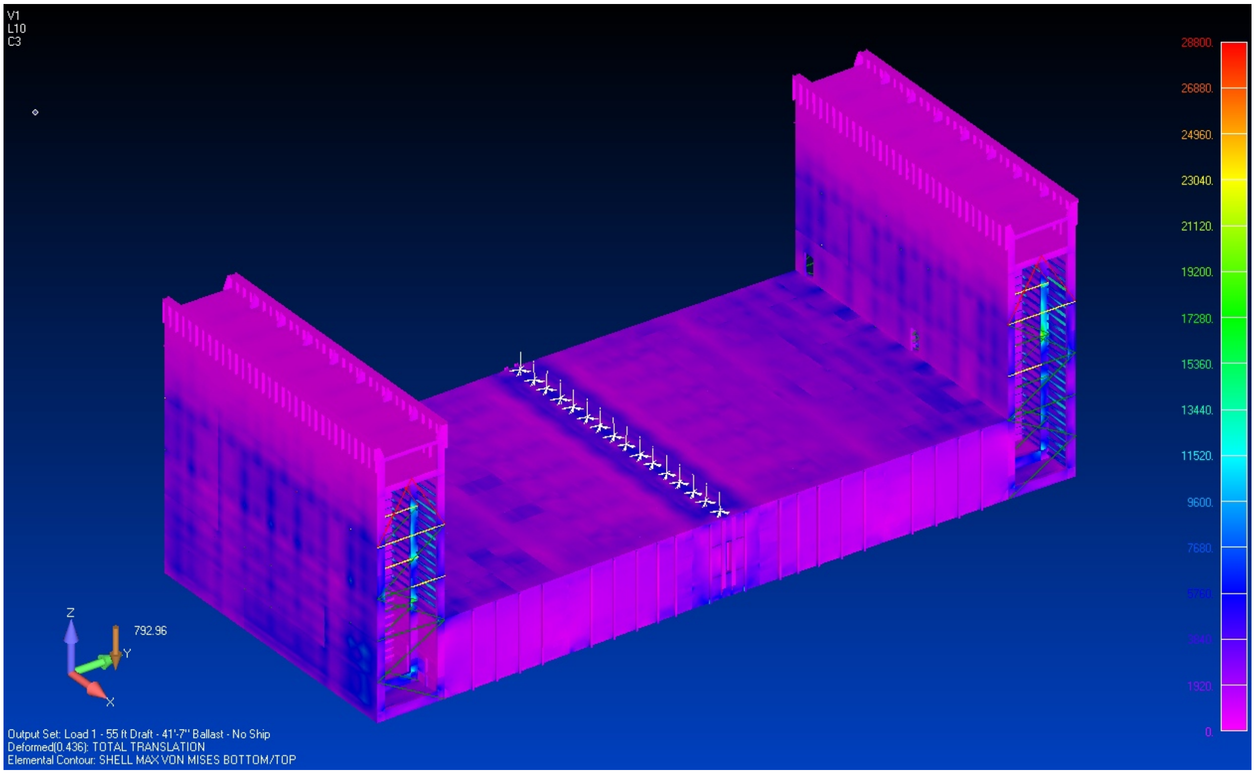

Figure 16 – Load Case 1 – 28,800 psi Allowable Stress

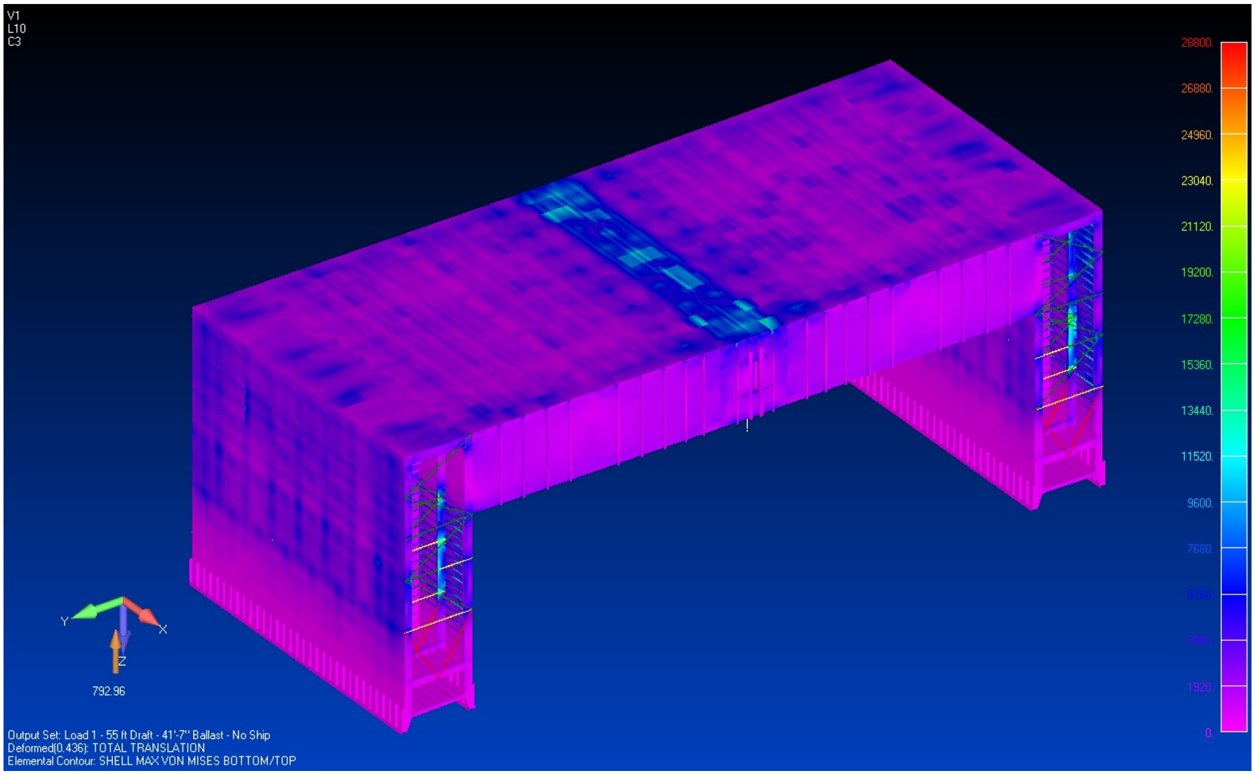

Figure 17 – Load Case 1 – 28,800 psi Allowable Stress – Inverted View

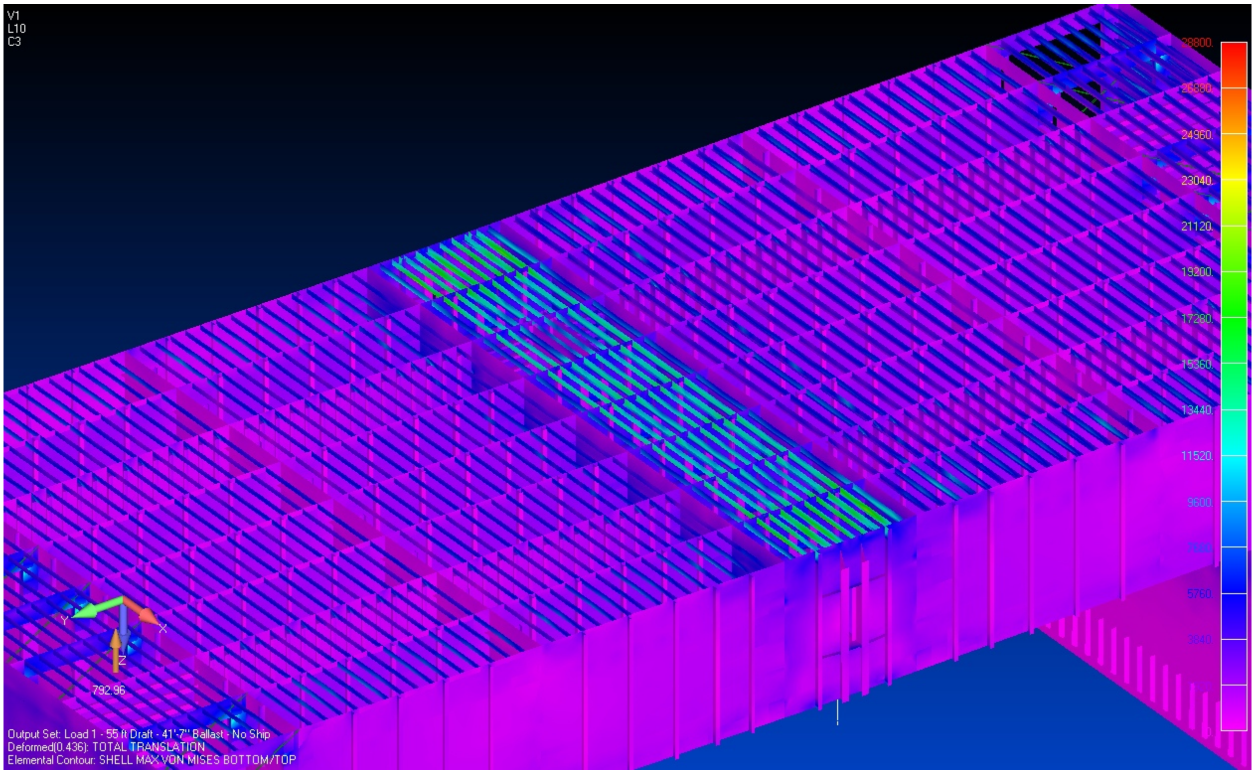

Figure 18 – Load Case 1 – 28,800 psi Allowable – Inverted View – Bottom Plate Not Shown

Stress Analysis – Load Case 2

Load Case 2 represents the maximum differential water pressure design condition of the dock. In this case, the draft is defined to be 46.75 ft., and the ballast water level in the tanks is 20 ft., or equal to the level of the pontoon deck at the intersection with the inboard wingwall. The ship weight in this condition is calculated based on the available buoyancy of the dock in this condition to support a ship. The maximum stress in the model is 27,782 psi. Maximum stresses are found in the outboard web frame structure and outboard wingwall stiffeners. The maximum beam stress in wingwall truss structure is 23,661 psi. These stresses are less than the allowable stress of 28,800 psi and are acceptable. Figure 19, Figure 20, and Figure 21 show the stress plots for Load Case 2 based on an allowable stress of 28,800 psi.

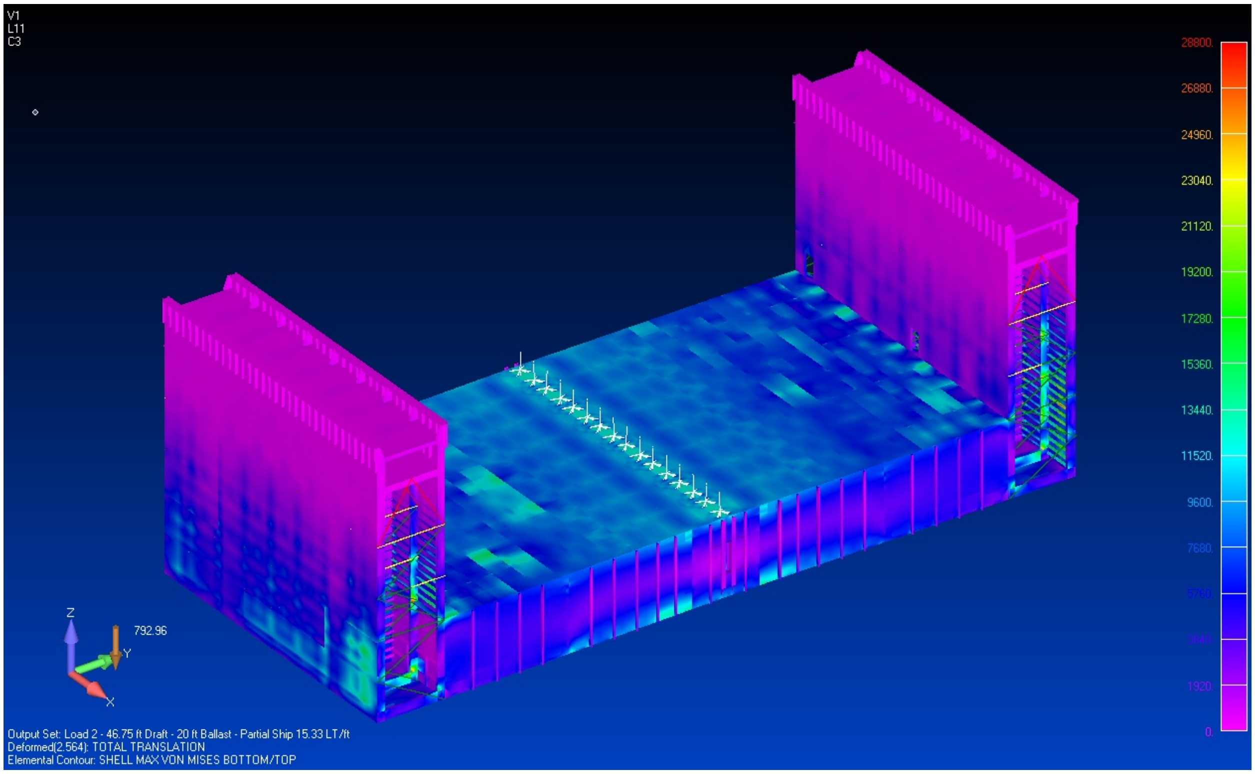

Figure 19 – Load Case 2 – 28,800 psi Allowable Stress

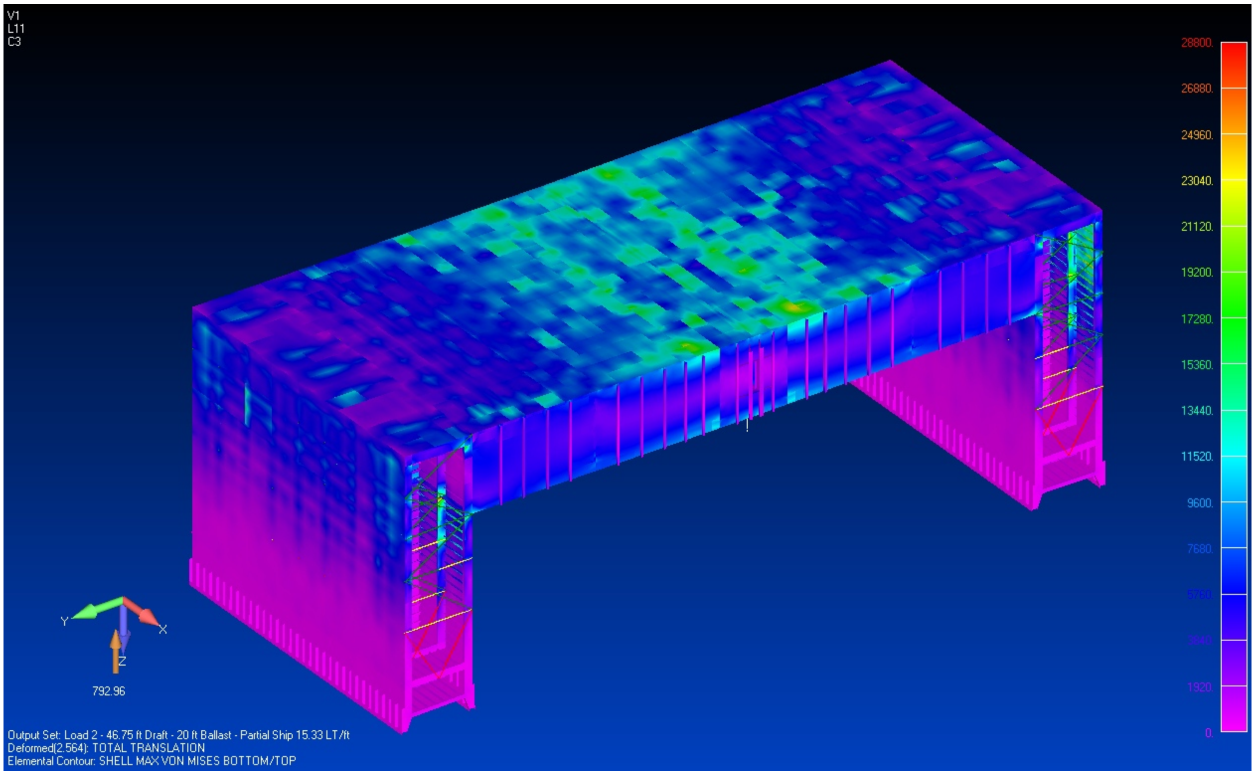

Figure 20 – Load Case 2 – 28,800 psi Allowable Stress – Inverted View

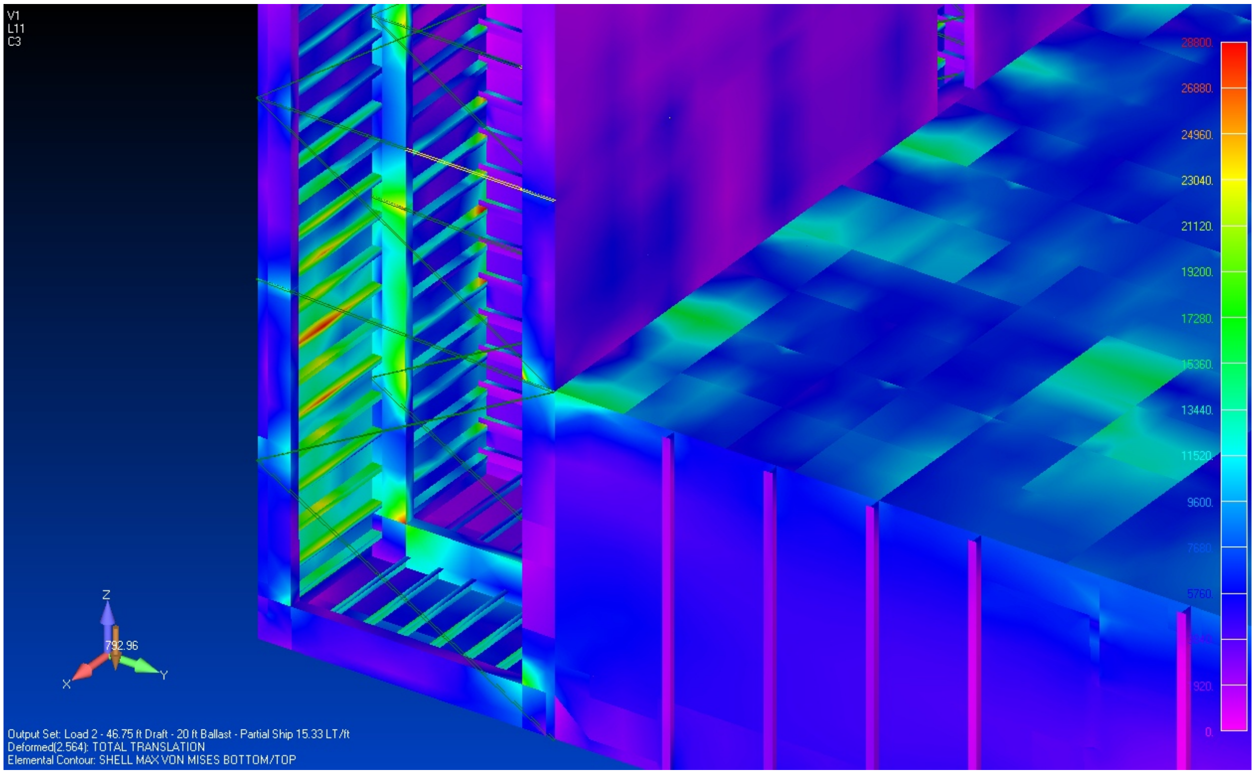

Figure 21 – Load Case 2 – 28,800 psi Allowable Stress – Outboard WW Stiffeners

Stress Analysis – Load Case 3

Load Case 3 represents the point of docking the ship where the draft of the dry dock is at the top of the keel blocks, and the entire weight of the ship is now bearing on the dock. The dry dock is modeled at a draft of 25.75 ft., and the entire ship load is applied. Ballast tanks are modeled to achieve equilibrium.

The maximum stress in the Mayari-R steel in the model is 47,816 psi in the bottom plating, which is greater than the allowable stress of 40,000 psi. The only locations where the Mayari-R steel exceeds the allowable stress are in certain locations in the bottom plating with “extreme” corrosion that is greater than 50% reduced thickness. The maximum stress in the A-36 steel in the model is 38,632 psi in the lower portion of the transverse web frames immediately outboard of the buoyancy compartment, which is greater than the allowable stress of 28,800 psi. These portions of the transverse web frames are the only locations where the A-36 steel in the model exceeds the allowable stress. The maximum beam stress in wingwall truss structure is 9,730 psi. Figure 22, Figure 23, and Figure 24 show the stress plots for Load Case 3.

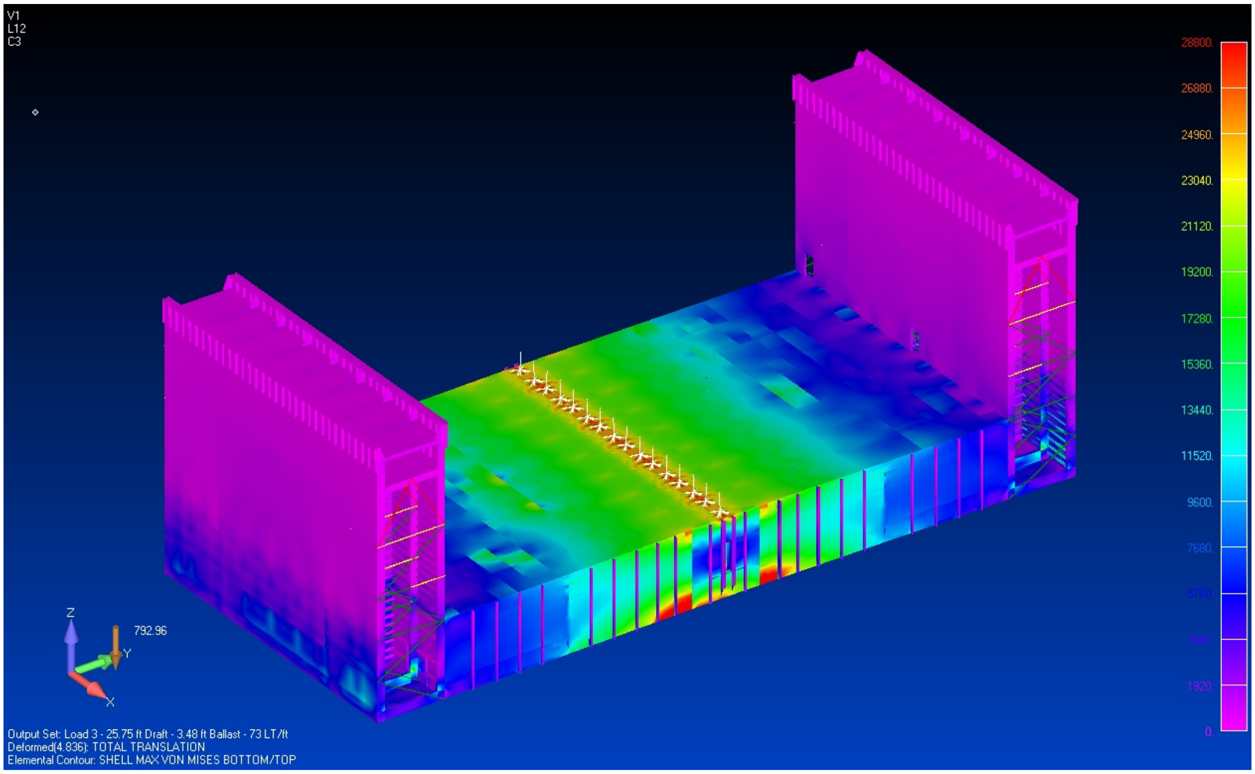

Figure 22 – Load Case 3 – 28,800 psi Allowable Stress

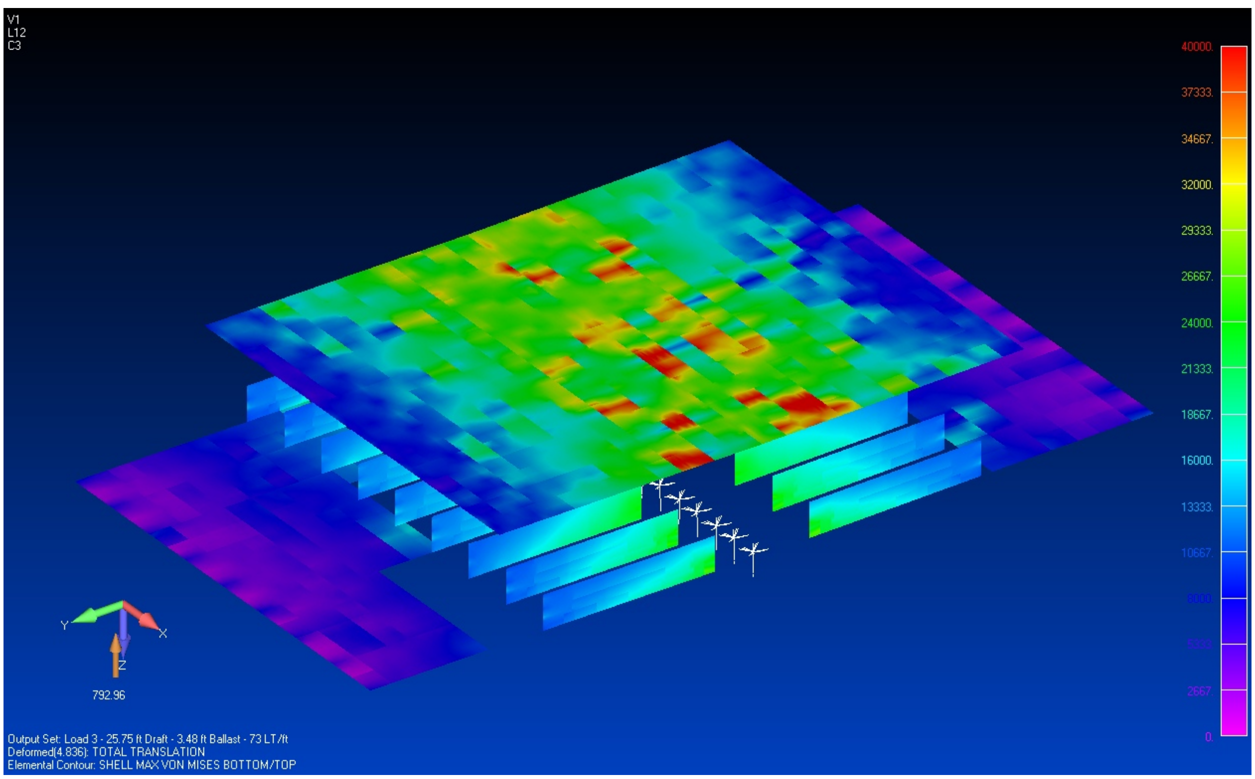

Figure 23 – Load Case 3 – Mayari-R – 40,000 psi Allowable – Inverted View

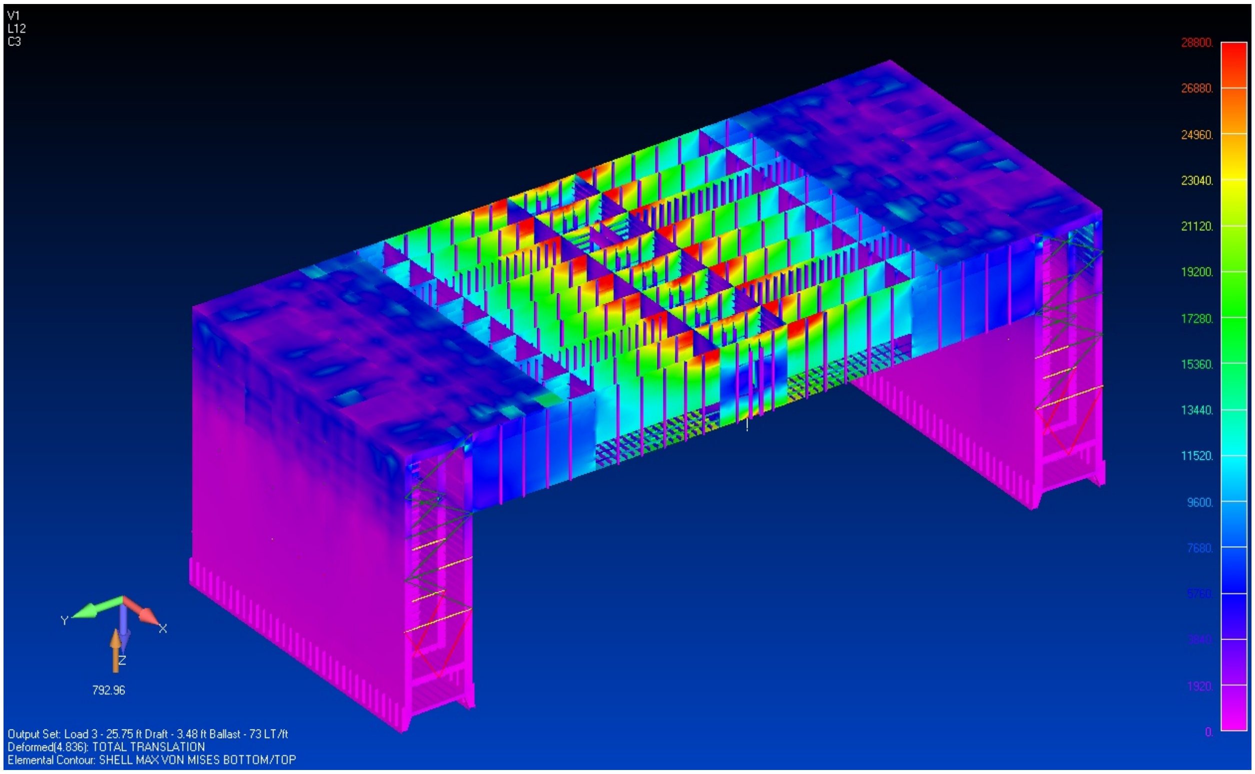

Figure 24 – Load Case 3 – A-36 Steel – 28,800 psi Allowable – Inverted View

Stress Analysis – Load Case 4

Load Case 4 represents the dock at the final stage of lifting the ship with ballast tanks at a minimum level. The draft of the dock is such to support the weight of the dock and the ship at equilibrium. The maximum stress in the Mayari-R steel in the model is 45,435 psi in the bottom plating, which is greater than the allowable stress of 40,000 psi. The only locations where the Mayari-R steel exceeds the allowable stress are in certain locations in the bottom plating with "extreme" corrosion that is greater than 50% reduced thickness. The maximum stress in the A-36 steel in the model is 37,715 psi in the lower portion of the transverse web frames immediately outboard of the buoyancy compartment, which is greater than the allowable stress of 28,800 psi. These portions of the transverse web frames are the only locations where the A-36 steel in the model exceeds the allowable stress. The maximum beam stress in the wingwall truss structure is 6,639 psi. The maximum stresses in Load Case 4 are exceeded by those in Load Case 3, and Load Case 3 remains the dominant load case. Figure 25, Figure 26, and Figure 27 show the stress plots for Load Case 4.

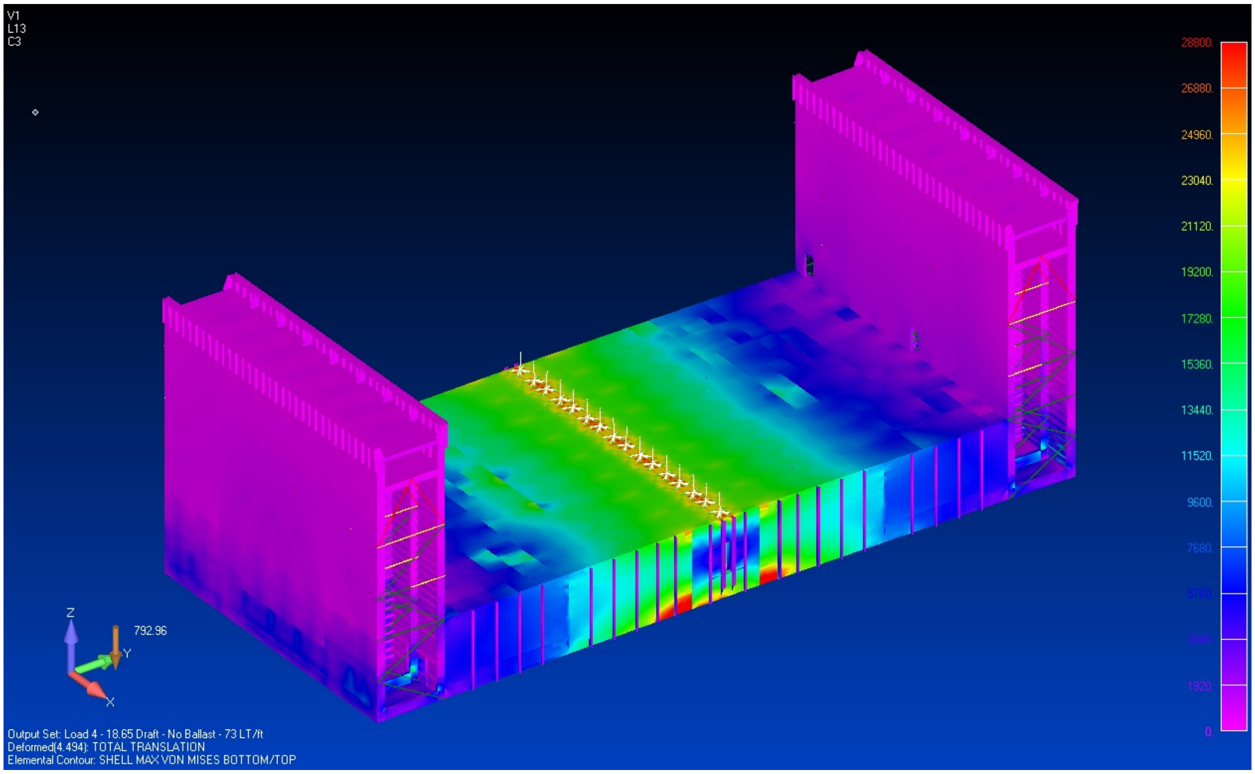

Figure 25 – Load Case 4 – 28,800 psi Allowable Stress

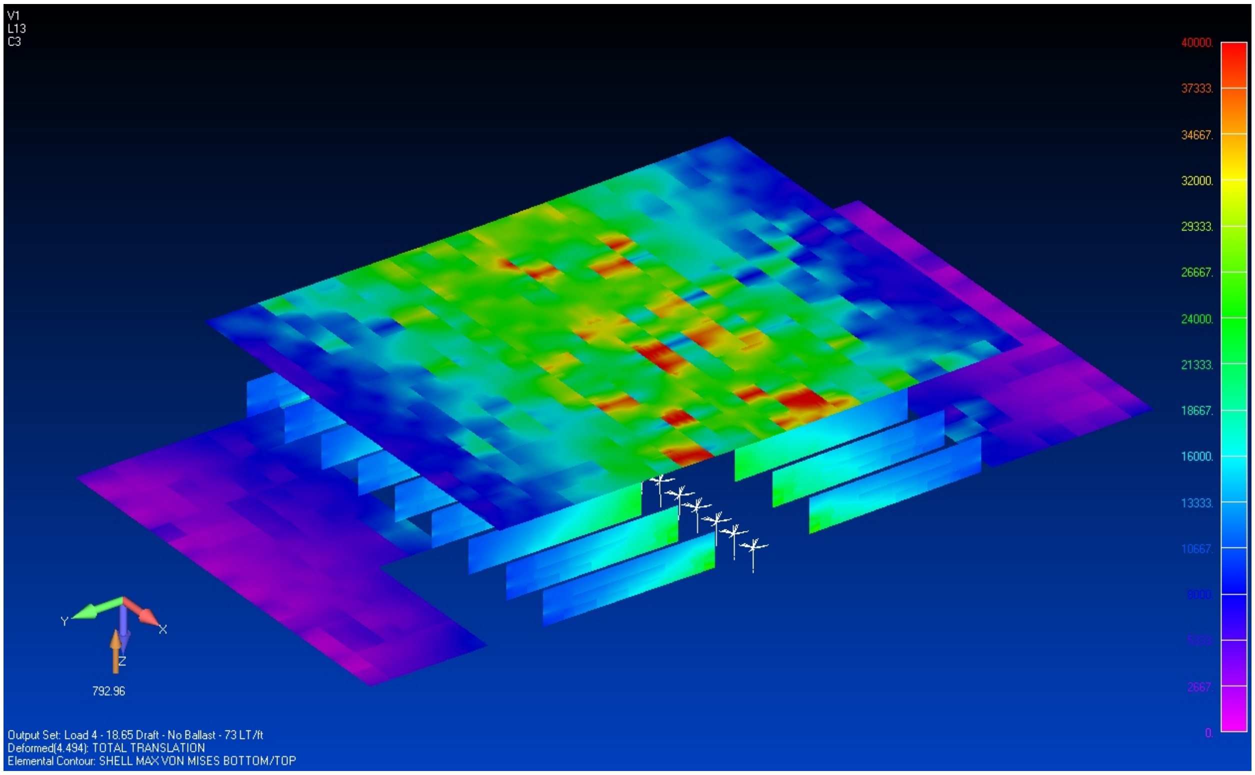

Figure 26 – Load Case 4 – Mayari-R – 40,000 psi Allowable – Inverted View

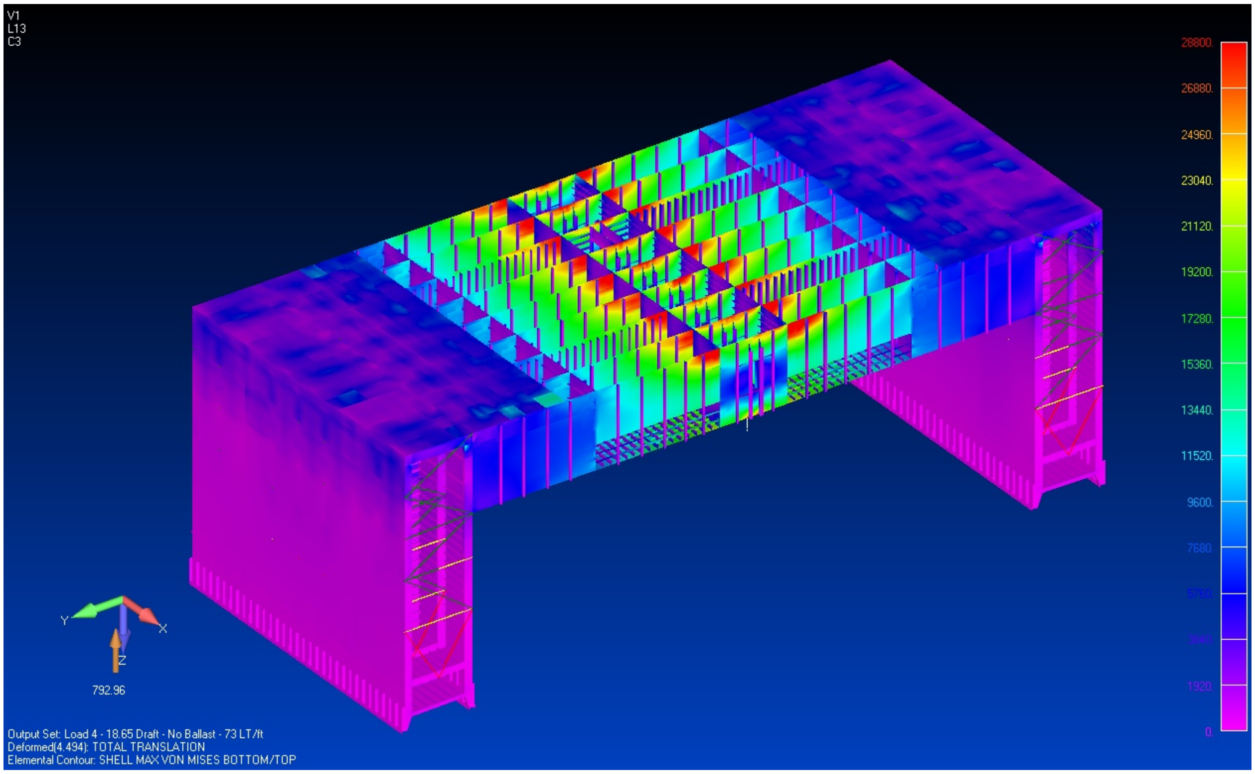

Figure 27 – Load Case 4 – A-36 Steel – 28,800 psi Allowable – Inverted View

Buckling Check

Buckling was checked in the local model for all four load cases. The members of most concern for buckling are the transverse web frame plates, transverse web frame truss beams, and the pontoon deck plating, as these are the members acting in compression during a typical docking cycle.

For the buckling check, we analyze linear buckling based on Euler's method whereby a critical buckling load is determined, which corresponds to a state of unstable equilibrium in the structure. Nastran reports buckling eigenvalues (λ), which correspond to the ratio between the critical buckling load and the applied load in the model. Eigenvalues greater than 1.00 (with appropriate margin) indicate that buckling is not a concern. Negative eigenvalues indicate that the member of concern is in tension, and may therefore be disregarded. Eigenvalues between 0.00 and 1.00 must be resolved. The minimum absolute buckling eigenvalue for each of the load cases is shown in Table 5.

Table 5 – Buckling Eigenvalues

Load Case	Buckling Eigenvalue	Location in Model
1	1.9895	Web Frame – Inboard of Inboard Wingwall
2	0.9871	Web Frame – Inboard of Inboard Wingwall
3	-1.0669	Web Frame – Outboard of Buoyancy Comp.
4	-1.0463	Web Frame – Outboard of Buoyancy Comp.

Load Cases 3 and 4 have buckling eigenvalues that are negative, indicating that the members of concern are in tension. Load Case 2 has a buckling eigenvalue of 0.9871. The buckling is seen in the transverse web frame near the inboard wingwall (see Figure 28), which is an area of compression in the web frames due to the external hydrostatic pressure and the global transverse shear stress in the corner between the pontoon and the wingwall. In actuality, this reported buckling eigenvalue is quite conservative for two reasons: 1. The web frame in this location is modeled with 25% reduced thickness while the survey reports found between 0% and 8.5% reduced thickness in the web frames in this location; 2. Brackets in way of the connections between the stiffeners and the transverse web frames were not modeled, as these are local details that do not contribute to the global strength of the structure. However, the brackets may have a significant effect by increasing the theoretical critical buckling load by a factor of up to 2.00 by changing the end connections of the transverse web frame from “pinned” to “fixed.” With these considerations in mind, it is determined that this buckling eigenvalue is acceptable as is.

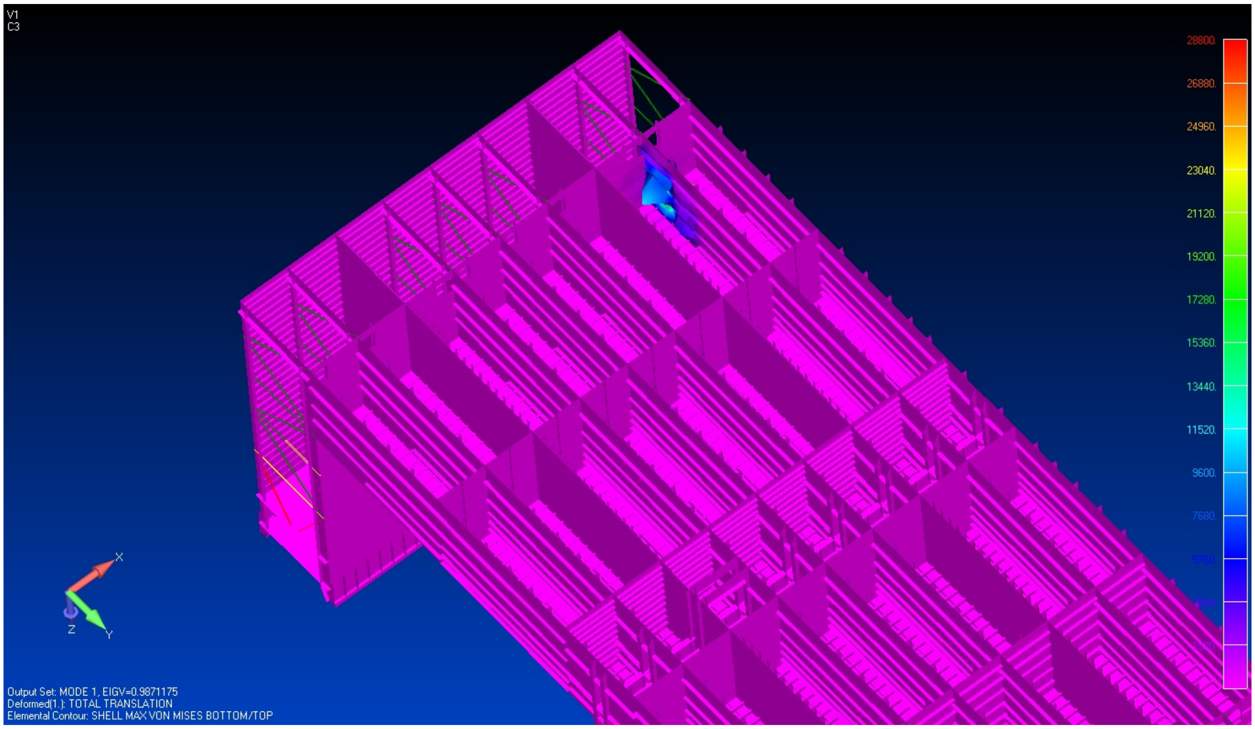

Figure 28 – Load Case 2 – Buckling in Transverse Web Frame – λ = 0.9871 – Inverted View

Stress Analysis – Maximum Lifting Load – Load Case 3

Load Case 3 is the dominant load case from the previous analyses. In order to determine the current lifting capacity of the dock, the ship load was iterated to determine the maximum ship load that can be currently safely lifted by the dock. This particular model was given properties that are deemed to reflect the greatest wastage found anywhere in the dry dock. Through iteration, this maximum ship load is determined to be 65 LT/ft. Figure 29, Figure 30, Figure 31, and Figure 32 show the stresses in the dock in Load Case 3 while lifting a ship load of 65 LT/ft. Note that Figure 31 is a “criteria” view showing the elements with stresses from corresponding Figure 30 that exceed the allowable stress of 28,800 psi. These elements exceeding the allowable are located in the hot spots at the corners of the web frames. The maximum stress shown in Figure 31 is 33,768 psi, which does exceed the allowable stress. The maximum stress shown in the Mayari-R steel in Figure 32 is 42,030 psi, which slightly exceeds the allowable stress of 40,000 psi. However, because the stresses quickly dissipate moving away from the element located in the hot spot, it is acceptable practice to somewhat exceed the allowable stress in these hot spot locations. It is recommended to accept these hot spot stresses as is.

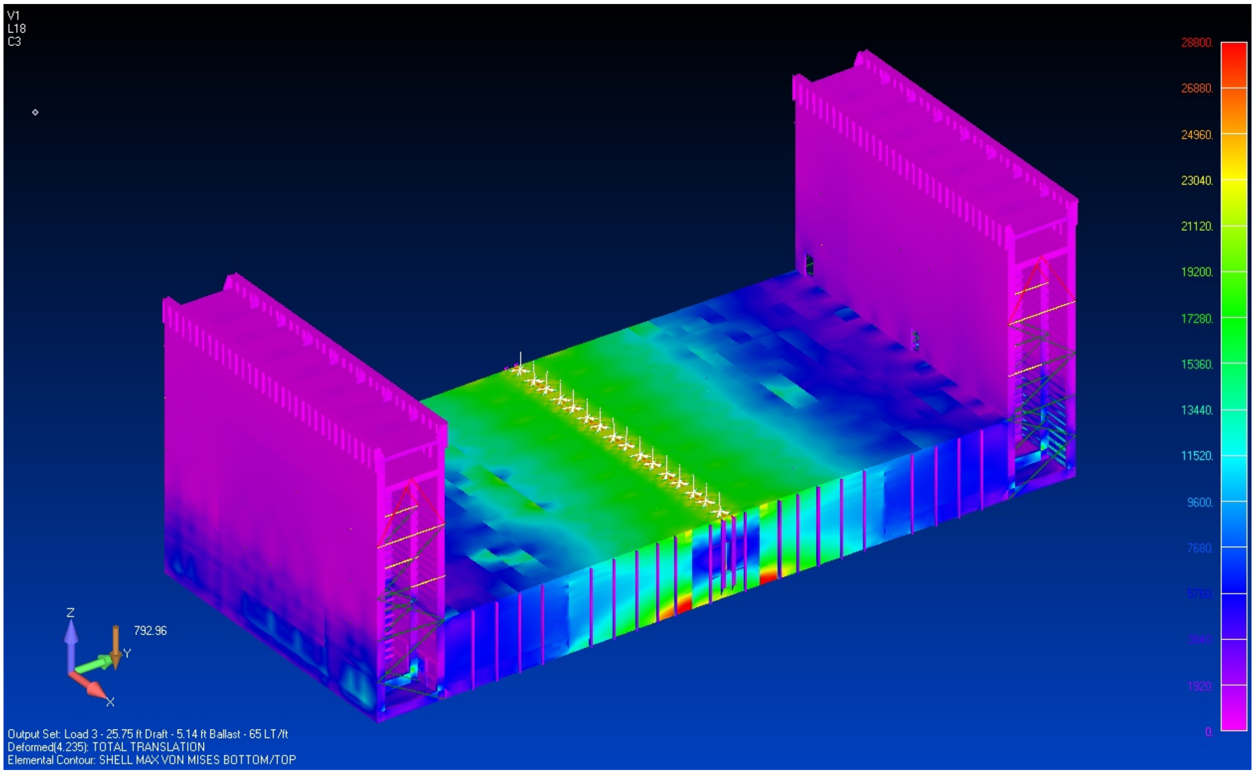

Figure 29 – Load Case 3 – 65 LT/ft. – A-36 Steel – 28,800 psi Allowable

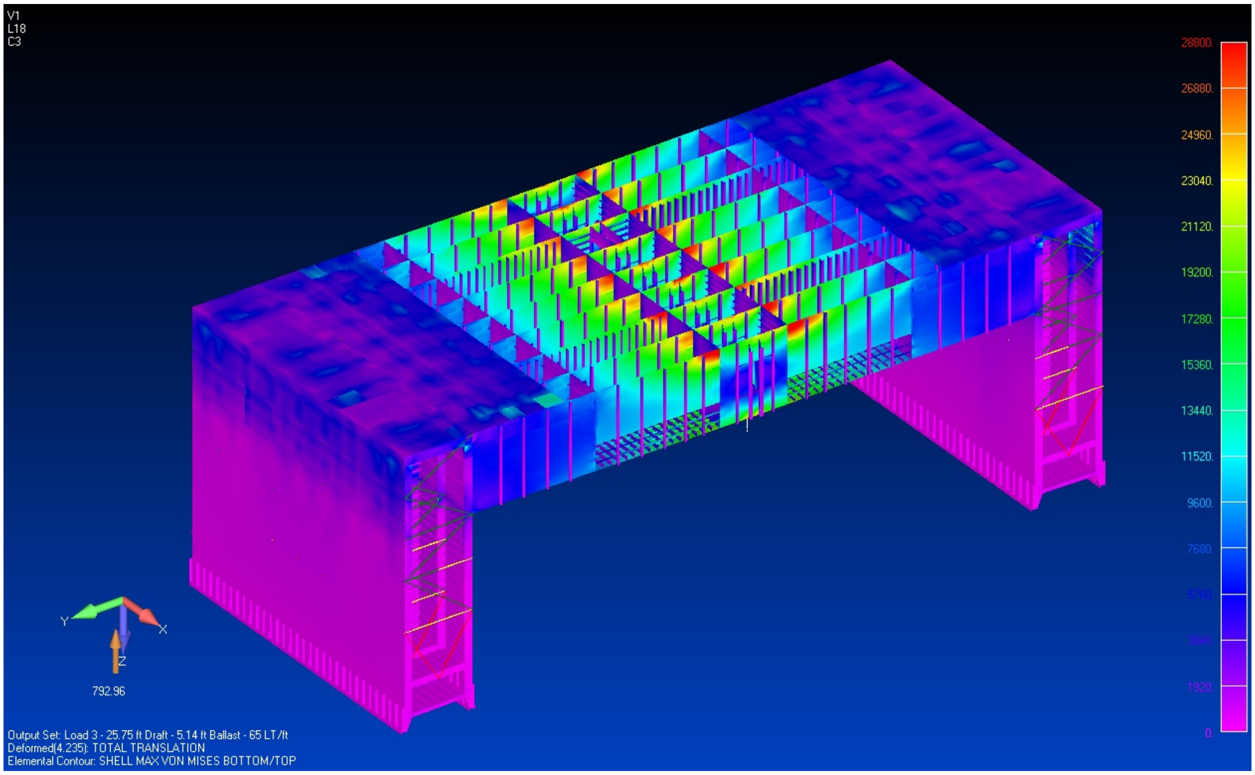

Figure 30 – Load Case 3 – 65 LT/ft. – A-36 Steel – 28,800 psi Allowable – Inverted View

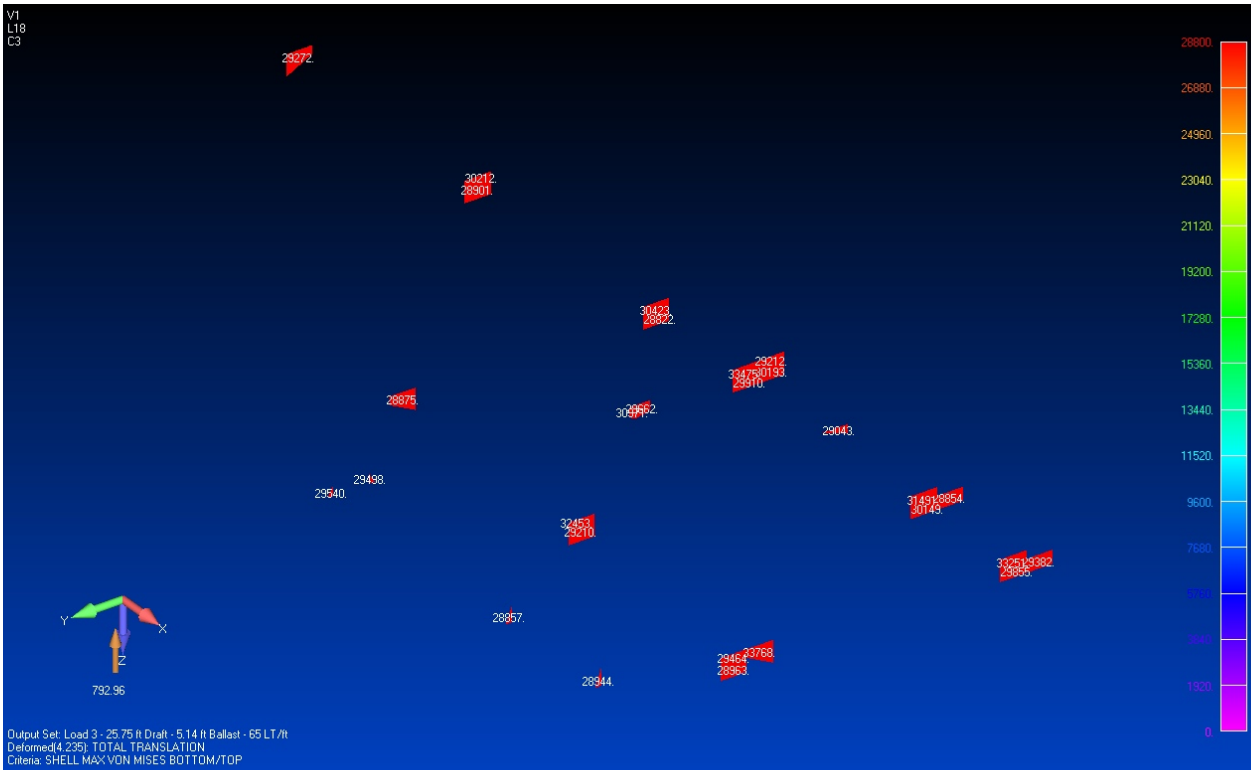

Figure 31 – Load Case 3 – 65 LT/ft. – A-36 Steel – 28,800 psi Allowable – Inverted View – Criteria

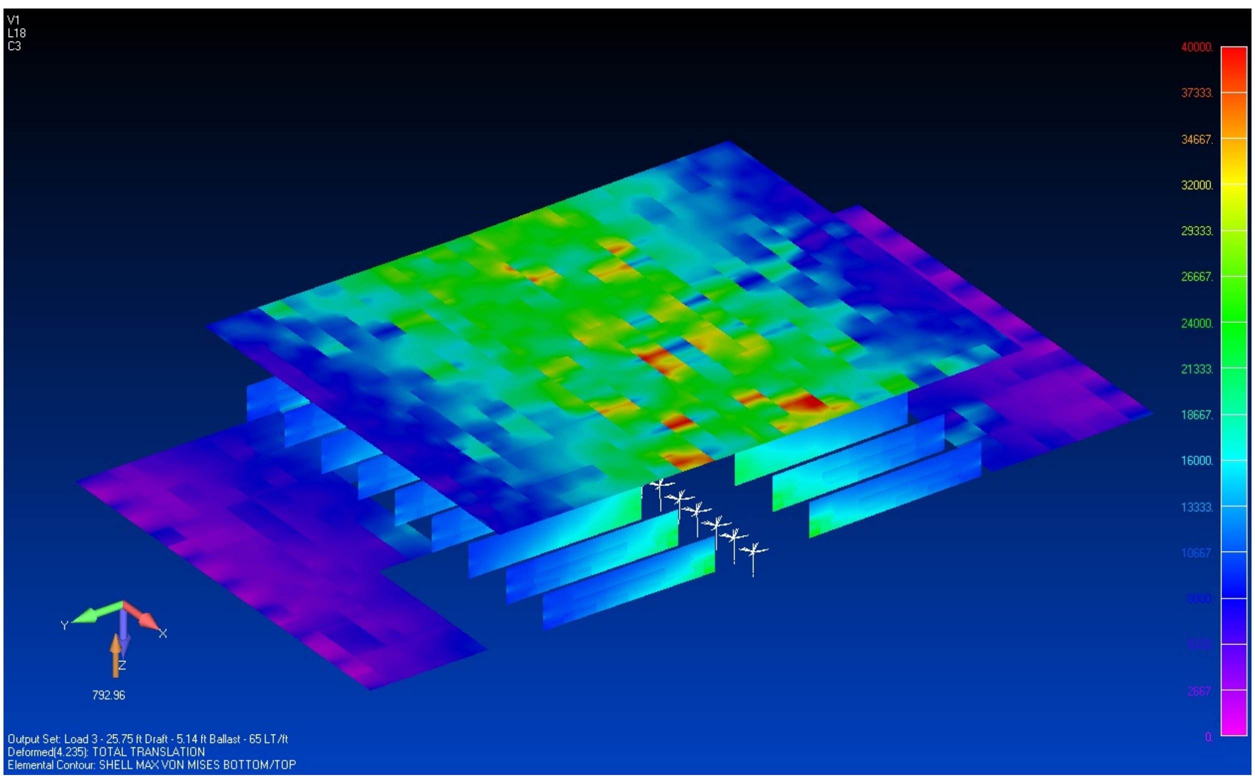

Figure 32 – Load Case 3 – 65 LT/ft. – Mayari-R – 40,000 psi Allowable – Inverted View

It was thusly determined that the dry dock section with the greatest wastage will have a dock lifting capacity of 65 LT/ft. To apply this capacity to the full length of the dock would yield a dock capacity of 52,000 LT maximum. However, this capacity would have to be reduced to allow the keel load maximums and minimums that are calculated for a docking. Not all of the dock is in this condition of corrosion. Other tanks have a greater dock lifting capacity and depending upon how the keel load from the ship aligns with these capacities, the dock lifting capacity may be improved upon.

To determine the aggregate lifting capacity of the dock, the local model was replicated and modified to reflect the corrosion properties of the dry dock in way of each pair of ballast tanks, except the end tanks. Then, the ship load applied to the dock was iterated to determine the maximum lifting capacity of the dock in way of each pair of dry dock ballast tanks. This lifting capacity is based upon lifting the ship using only keel blocks, with no side blocks. The results are similar to what is found for the local model in the section from Frame 18 to 26; hot spots will vary with wastage as will the lifting capacity. Figure 33, Figure 34, Figure 35, and Figure 36 show the stresses in the section of the dock from Frame 30 to 38, where the dock has the least wastage, while lifting a ship load of 75 LT/ft. Notice that the stress patterns and levels are very similar between this section of the dock at 75 LT/ft. and the section between Frame 18 and 26 at 65 LT/ft. This section of the dock is able to lift a greater ship load at the same stress levels.

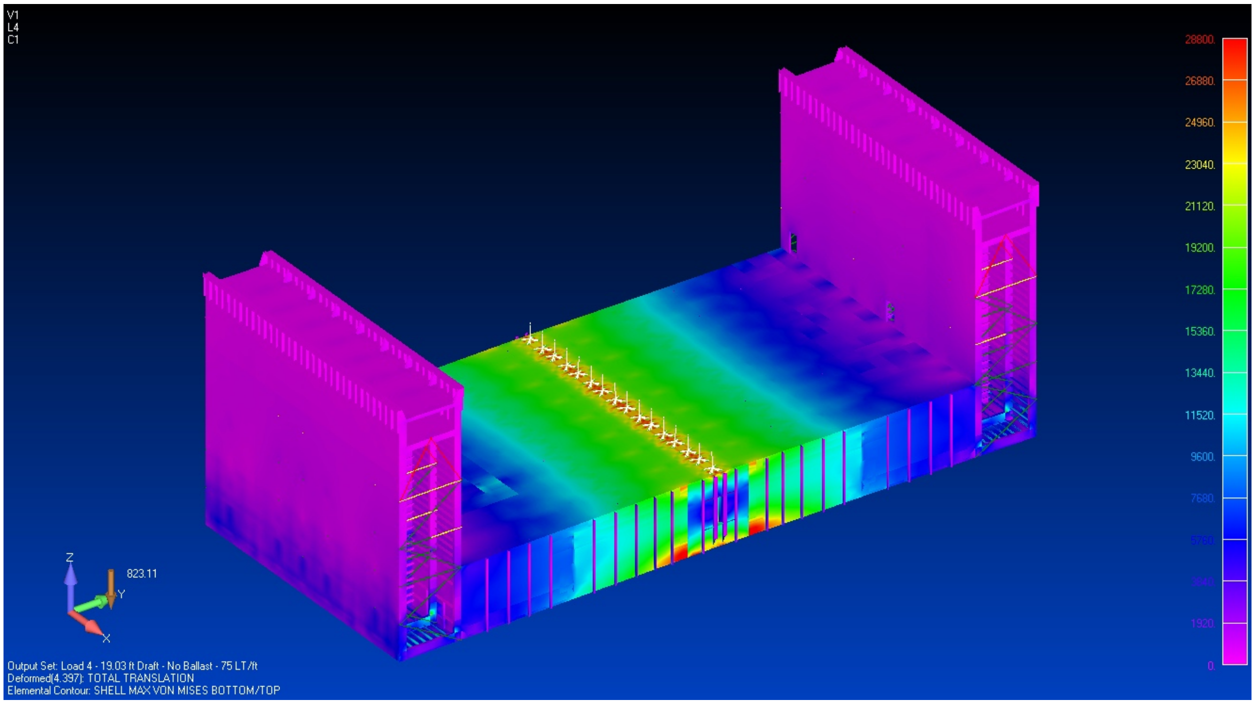

Figure 33 – Load Case 4 – Frame 30 to 38 – 75 LT/ft. – A-36 Steel – 28,800 psi Allowable

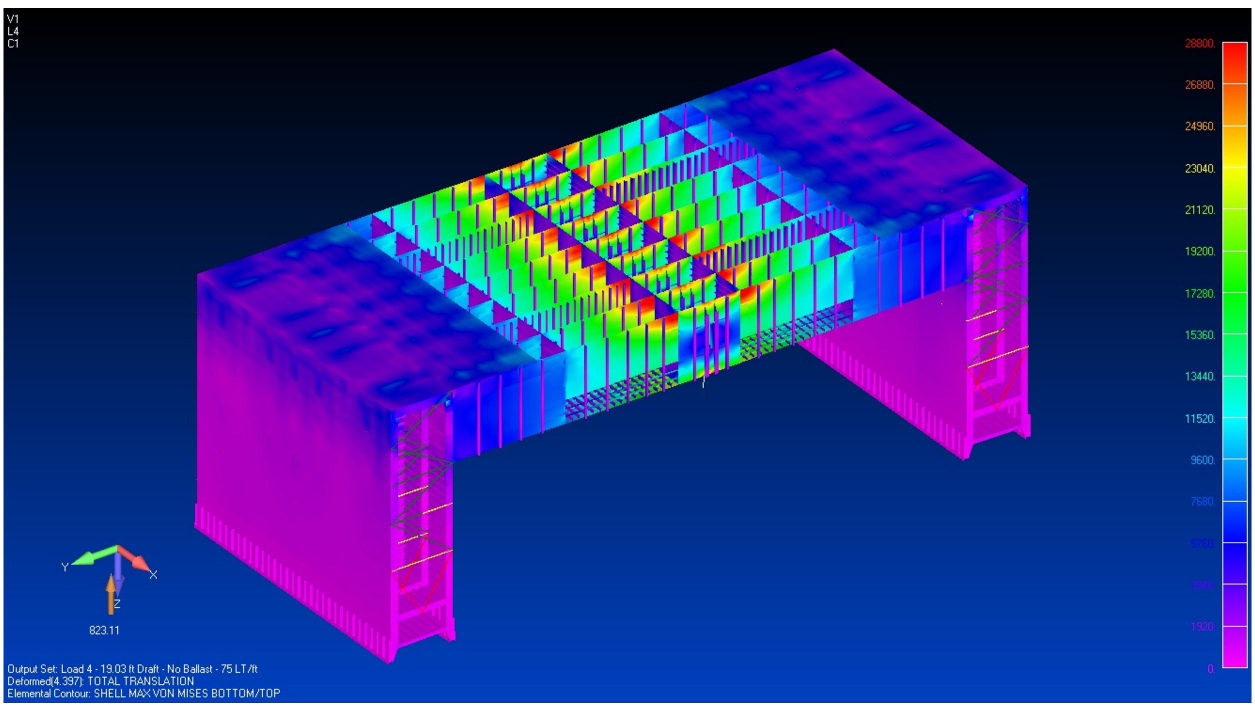

Figure 34 – Load Case 4 – Frame 30 to 38 – 75 LT/ft. – A-36 Steel – 28,800 psi Allowable – Inverted View

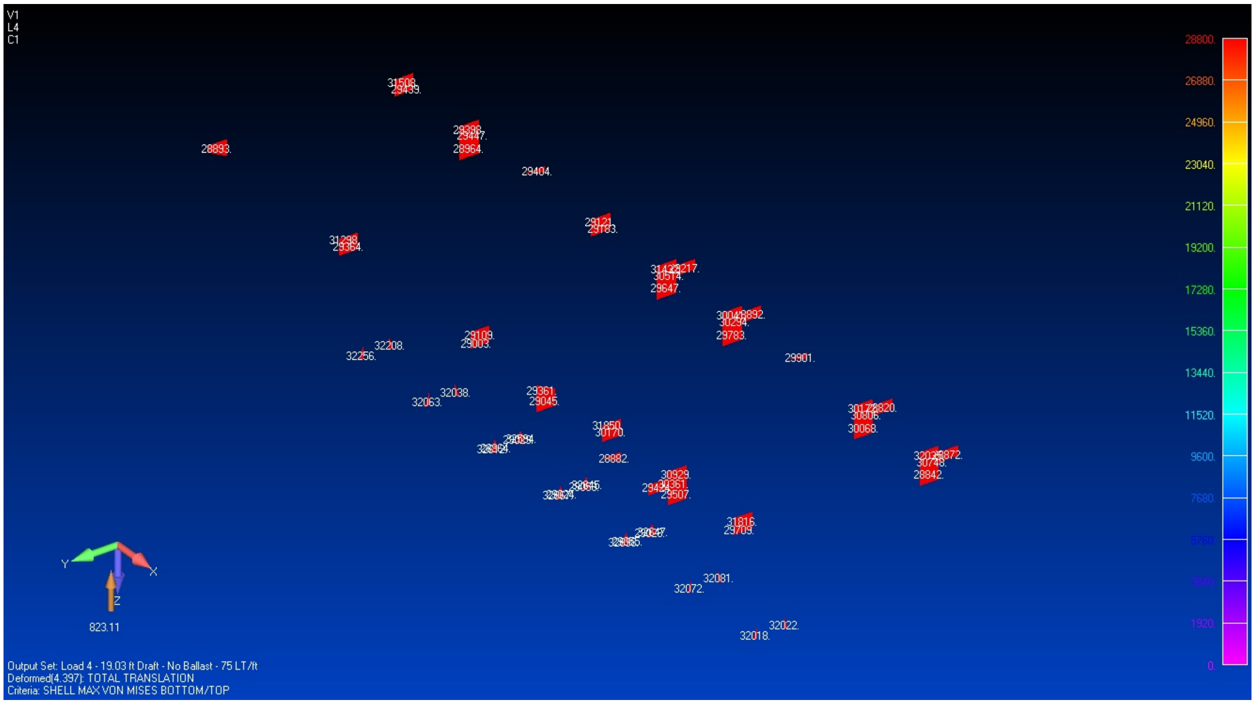

Figure 35 – Load Case 4 – Frame 30 to 38 – 75 LT/ft. – A-36 Steel – 28,800 psi Allowable – Inverted View – Criteria

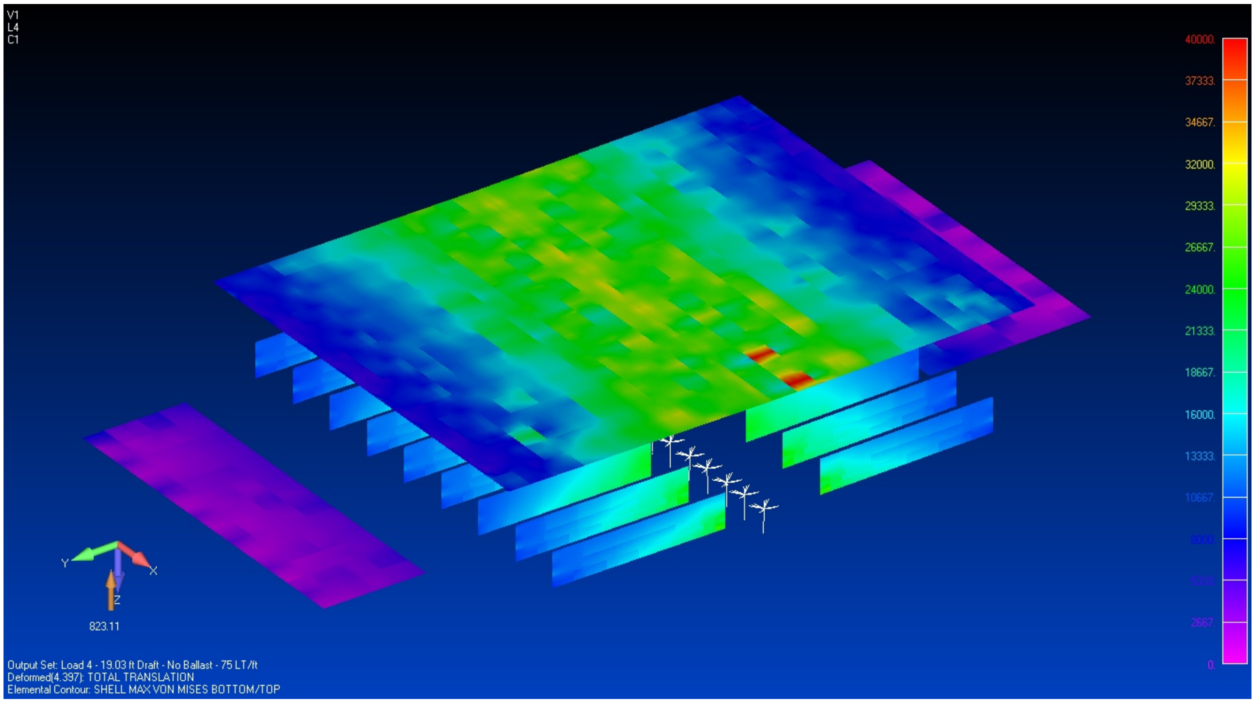

Figure 36 – Load Case 4 – Frame 30 to 38 – 75 LT/ft. – Mayari-R – 40,000 psi Allowable – Inverted View

The lifting capacity in way of each pair of ballast tanks was averaged with the lifting capacity of the set of tanks immediately forward and aft of it. This serves to smooth out the discontinuities in the lifting capacity curve due to significant variations in corrosion between two tanks, as well as to account for the structural interaction between adjacent tanks that is not adequately represented by the local model that is only 80 ft. long. Figure 37 shows the allowable lifting capacity of the dock along the length of the dock developed according to the above-mentioned procedure. The integral of this allowable lifting load curve along the entire length of the dock yields the total maximum lifting capacity of the dry dock, which is 54,800 LT. The dock loading capacity varies from 65 LT/ft. to 75 LT/ft. The use of side blocks better distributes the weight of the ship transversely along the dock, thus decreasing the transverse sagging moment in the dock. Therefore, the allowable lifting capacity of the dock where side blocks are present is 75 LT/ft. anywhere along the length of the dock. Appendix D details the allowable lifting capacity of the dock in way of each ballast tank.

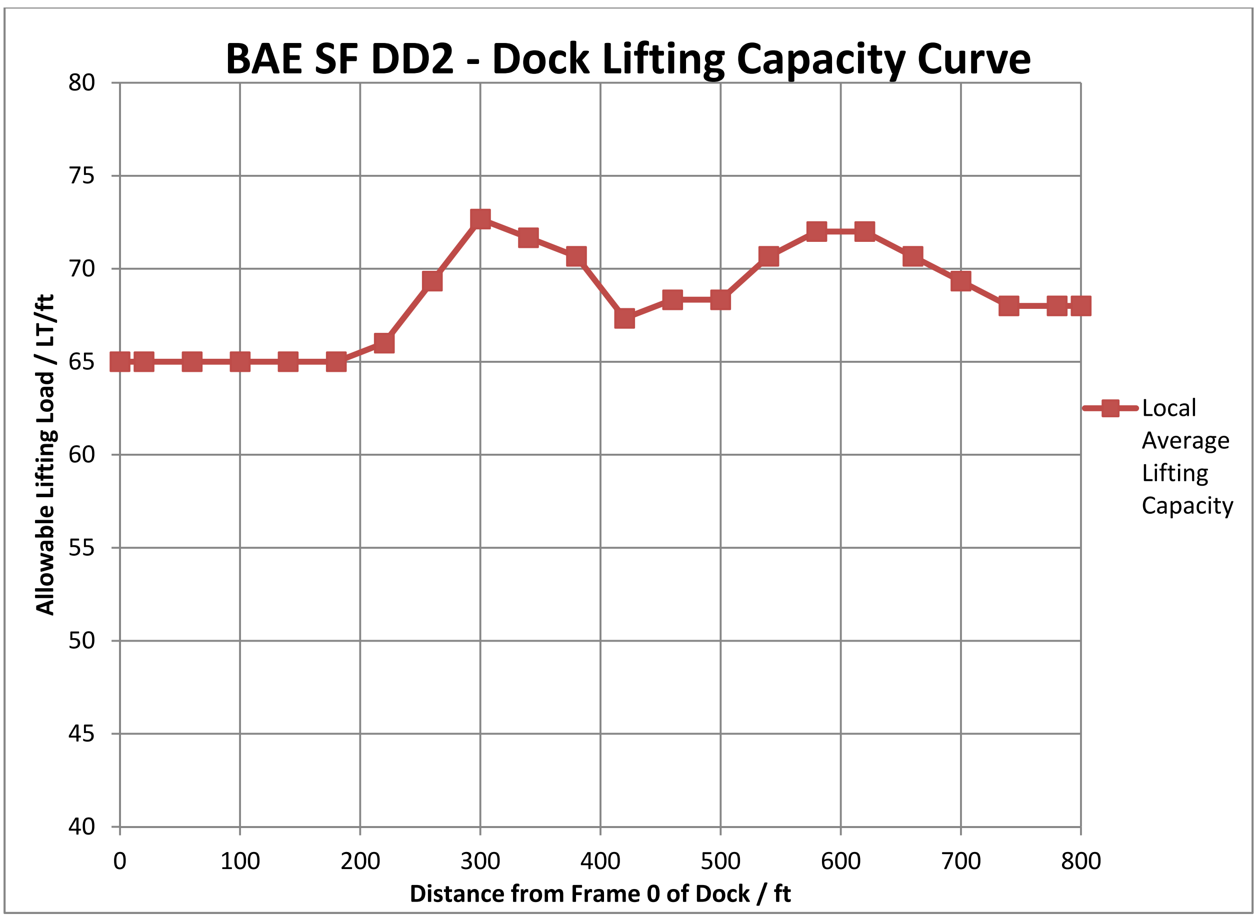

Figure 37 – Dock Lifting Capacity Curve

Results Discussion and Recommendations

The primary stress pattern shown by the analyses is that of transverse bending of the dry dock. This is due to the load of the ship being primarily carried through the keel blocks along the centerline of the dock, while the water pressure on the underside of the dock acts uniformly upward. This results in a significant transverse sagging moment in the dock. Longitudinal bending of the dock is smaller in comparison and is controlled by the dockmaster by monitoring and controlling the longitudinal deformation of the dock by varying the water levels of individual ballast tanks to minimize the longitudinal bending moment. Vertical deflections in the dock due to the longitudinal stresses are monitored throughout the lifting operation and kept to within a maximum of three (3) inches. However, there is no active way to mitigate the transverse bending of the dock throughout the lifting operation. Note that maximum transverse bending stresses occur in transverse web frames and bulkheads that are fabricated of ordinary steel whereas when combined with longitudinal bending stresses, the maximum stress occurs in shell plating that is higher strength steel. It is prudent to continue monitoring and controlling the vertical deflection of the dock from tank loading to within a maximum of three (3) inches, as this minimizes biaxial stresses that occur in the shell plating.

Based on the local analyses of the dock in way of each pair of ballast tanks, the maximum ship load that can be lifted along the entire 800 ft. length of the dock without exceeding the allowable stresses, except in hot spots, is determined to be 54,800 LT. Hot spots are allowed to see stresses between allowable and yield strength because the stresses quickly dissipate moving away from the element located in the hot spot.

Appendix A – Finite Element Model - Element Properties

Table of Contents

Plate Elements

Property No.	Property Name	Thick.	%Reduction	Reduced Thickness	Material
		inches		inches	
1	Plate 10.2# (1/4)	0.25	0%	0.25	A-36
2	Plate 10.2# (1/4) - Sat. - 25% Red.	0.25	25%	0.1875	A-36
3	Plate 15.3# (3/8)	0.375	0%	0.375	A-36
4	Plate 15.3# (3/8) - Sat. - 25% Red.	0.375	25%	0.28125	A-36
5	Plate 15.3# (3/8) - Marg. - 35% Red.	0.375	35%	0.24375	A-36
6	Plate 15.3# (3/8) - Unsat. - 50% Red.	0.375	50%	0.1875	A-36
7	Plate 17.85# (7/16)	0.4375	0%	0.4375	A-36
8	Plate 17.85# (7/16) - New - 15% Red.	0.4375	15%	0.371875	A-36
9	Plate 17.85# (7/16) - Sat. - 25% Red.	0.4375	25%	0.328125	A-36
10	Plate 17.85# (7/16) - Marg. - 35% Red.	0.4375	35%	0.284375	A-36
11	Plate 17.85# (7/16) - Unsat. - 50% Red.	0.4375	50%	0.21875	A-36
12	Plate 17.85# (7/16) - Extreme - 75% Red.	0.4375	75%	0.109375	A-36
13	Plate 17.85# (7/16) - New - 15% Red. - Mayari-R	0.4375	15%	0.371875	Mayari-R
14	Plate 17.85# (7/16) - Sat. - 25% Red. - Mayari-R	0.4375	25%	0.328125	Mayari-R
15	Plate 17.85# (7/16) - Marg. - 35% Red. - Mayari-R	0.4375	35%	0.284375	Mayari-R
16	Plate 17.85# (7/16) - Unsat. - 50% Red. - Mayari-R	0.4375	50%	0.21875	Mayari-R
17	Plate 17.85# (7/16) - Extreme - 75% Red. - Mayari-R	0.4375	75%	0.109375	Mayari-R
18	Plate 20.4# (1/2)	0.5	0%	0.5	A-36
19	Plate 20.4# (1/2) - New - 15% Red.	0.5	15%	0.425	A-36
20	Plate 20.4# (1/2) - Sat. - 25% Red.	0.5	25%	0.375	A-36
21	Plate 20.4# (1/2) - Marg. - 35% Red.	0.5	35%	0.325	A-36
22	Plate 20.4# (1/2) - Unsat. - 50% Red.	0.5	50%	0.25	A-36
23	Plate 20.4# (1/2) - Extreme - 75% Red.	0.5	75%	0.125	A-36
24	Plate 20.4# (1/2) - New - 15% Red. - Mayari-R	0.5	15%	0.425	Mayari-R
25	Plate 20.4# (1/2) - Sat. - 25% Red. - Mayari-R	0.5	25%	0.375	Mayari-R

Property No.	Property Name	Thick.	%Reduction	Reduced Thickness	Material
		inches		inches	
26	Plate 20.4# (1/2) - Marg. - 35% Red. - Mayari-R	0.5	35%	0.325	Mayari-R
27	Plate 20.4# (1/2) - Unsat. - 50% Red. - Mayari-R	0.5	50%	0.25	Mayari-R
28	Plate 20.4# (1/2) - Extreme - 75% Red. - Mayari-R	0.5	75%	0.125	Mayari-R
29	Plate 23# (9/16)	0.5625	0%	0.5625	A-36
30	Plate 23# (9/16) - New - 15% Red.	0.5625	15%	0.478125	A-36
31	Plate 23# (9/16) - Sat. - 25% Red.	0.5625	25%	0.421875	A-36
32	Plate 23# (9/16) - Marg. - 35% Red.	0.5625	35%	0.365625	A-36
33	Plate 23# (9/16) - Unsat. - 50% Red.	0.5625	50%	0.28125	A-36
34	Plate 25.5# (5/8)	0.625	0%	0.625	A-36
35	Plate 25.5# (5/8) - New - 15% Red.	0.625	15%	0.53125	A-36
36	Plate 25.5# (5/8) - Sat. - 25% Red.	0.625	25%	0.46875	A-36
37	Plate 25.5# (5/8) - Marg. - 35% Red.	0.625	35%	0.40625	A-36
38	Plate 25.5# (5/8) - Unsat. - 50% Red.	0.625	50%	0.3125	A-36
39	Plate 28.1# (11/16)	0.6875	0%	0.6875	A-36
40	Plate 28.1# (11/16) - Sat. - 25% Red.	0.6875	25%	0.515625	A-36
41	Plate 28.1# (11/16) - Marg. - 35% Red.	0.6875	35%	0.446875	A-36
42	Plate 28.1# (11/16) - Unsat. - 50% Red.	0.6875	50%	0.34375	A-36
43	Plate 30.6# (3/4)	0.75	0%	0.75	A-36
44	Plate 30.6# (3/4) - New - 15% Red.	0.75	15%	0.6375	A-36
45	Plate 30.6# (3/4) - Sat. - 25% Red.	0.75	25%	0.5625	A-36
46	Plate 30.6# (3/4) - Marg. - 35% Red.	0.75	35%	0.4875	A-36
47	Plate 30.6# (3/4) - Unsat. - 50% Red.	0.75	50%	0.375	A-36
48	Plate 33.2# (13/16)	0.8125	0%	0.8125	A-36
49	Plate 33.2# (13/16) - Sat. - 25% Red.	0.8125	25%	0.609375	A-36
50	Plate 33.2# (13/16) - Marg. - 35% Red.	0.8125	35%	0.528125	A-36
51	Plate 33.2# (13/16) - Unsat. - 50% Red.	0.8125	50%	0.40625	A-36
52	Plate 35.7# (7/8)	0.875	0%	0.875	A-36
53	Plate 35.7# (7/8) - Sat. - 25% Red.	0.875	25%	0.65625	A-36
54	Plate 35.7# (7/8) - Marg. - 35% Red.	0.875	35%	0.56875	A-36

Property No.	Property Name	Thick.	%Reduction	Reduced Thickness	Material
		inches		inches	
55	Plate 35.7# (7/8) - Unsat. - 50% Red.	0.875	50%	0.4375	A-36
56	Plate 38.3# (15/16)	0.9375	0%	0.9375	A-36
57	Plate 38.3# (15/16) - Sat. - 25% Red.	0.9375	25%	0.703125	A-36
58	Plate 38.3# (15/16) - Marg. - 35% Red.	0.9375	35%	0.609375	A-36
59	Plate 38.3# (15/16) - Unsat. - 50% Red.	0.9375	50%	0.46875	A-36
60	Plate 40.8# (1)	1	0%	1	A-36
61	Plate 40.8# (1) - New - 15% Red.	1	15%	0.85	A-36
62	Plate 40.8# (1) - Sat. - 25% Red.	1	25%	0.75	A-36
63	Plate 40.8# (1) - Marg. - 35% Red.	1	35%	0.65	A-36
64	Plate 40.8# (1) - Unsat. - 50% Red.	1	50%	0.5	A-36
65	Plate 45.9# (1-1/8)	1.125	0%	1.125	A-36
66	Plate 45.9# (1-1/8) - Sat. - 25% Red.	1.125	25%	0.84375	A-36
67	Plate 45.9# (1-1/8) - Marg. - 35% Red.	1.125	35%	0.73125	A-36
68	Plate 45.9# (1-1/8) - Unsat. - 50% Red.	1.125	50%	0.5625	A-36
69	Plate ST 8x25# Flange (0.628)	0.628	0%	0.628	A-36
70	Plate ST 8x25# Flange (0.628) - Sat. - 25% Red.	0.628	25%	0.471	A-36
71	Plate ST 8x25# Flange (0.628) - Marg. - 35% Red.	0.628	35%	0.4082	A-36
72	Plate ST 8x25# Flange (0.628) - Unsat. - 50% Red.	0.628	50%	0.314	A-36
73	Plate ST 8x25# Web (0.380)	0.38	0%	0.38	A-36
74	Plate ST 8x25# Web (0.380) - Sat. - 25% Red.	0.38	25%	0.285	A-36
75	Plate ST 8x25# Web (0.380) - Marg. - 35% Red.	0.38	35%	0.247	A-36
76	Plate ST 8x25# Web (0.380) - Unsat. - 50% Red.	0.38	50%	0.19	A-36
77	Plate ST 9x27.35# Flange (0.691)	0.691	0%	0.691	A-36
78	Plate ST 9x27.35# Flange (0.691) - Sat. - 25% Red.	0.691	25%	0.51825	A-36
79	Plate ST 9x27.35# Flange (0.691) - Marg. - 35% Red.	0.691	35%	0.44915	A-36
80	Plate ST 9x27.35# Flange (0.691) - Unsat. - 50% Red.	0.691	50%	0.3455	A-36

Property No.	Property Name	Thick.	%Reduction	Reduced Thickness	Material
		inches		inches	
81	Plate ST 9x27.35# Web (0.461)	0.461	0%	0.461	A-36
82	Plate ST 9x27.35# Web (0.461) - Sat. - 25% Red.	0.461	25%	0.34575	A-36
83	Plate ST 9x27.35# Web (0.461) - Marg. - 35% Red.	0.461	35%	0.29965	A-36
84	Plate ST 9x27.35# Web (0.461) - Unsat. - 50% Red.	0.461	50%	0.2305	A-36
85	Plate ST 9x30# Flange (0.695)	0.695	0%	0.695	A-36
86	Plate ST 9x30# Flange (0.695) - Sat. - 25% Red.	0.695	25%	0.52125	A-36
87	Plate ST 9x30# Flange (0.695) - Marg. - 35% Red.	0.695	35%	0.45175	A-36
88	Plate ST 9x30# Flange (0.695) - Unsat. - 50% Red.	0.695	50%	0.3475	A-36
89	Plate ST 9x30# Web (0.416)	0.416	0%	0.416	A-36
90	Plate ST 9x30# Web (0.416) - Sat. - 25% Red.	0.416	25%	0.312	A-36
91	Plate ST 9x30# Web (0.416) - Marg. - 35% Red.	0.416	35%	0.2704	A-36
92	Plate ST 9x30# Web (0.416) - Unsat. - 50% Red.	0.416	50%	0.208	A-36
93	Plate ST 10x32.7# Flange (0.789)	0.789	0%	0.789	A-36
94	Plate ST 10x32.7# Flange (0.789) - New - 15% Red.	0.789	15%	0.67065	A-36
95	Plate ST 10x32.7# Flange (0.789) - Sat. - 25% Red.	0.789	25%	0.59175	A-36
96	Plate ST 10x32.7# Flange (0.789) - Marg. - 35% Red.	0.789	35%	0.51285	A-36
97	Plate ST 10x32.7# Flange (0.789) - Unsat. - 50% Red.	0.789	50%	0.3945	A-36
98	Plate ST 10x32.7# Web (0.500)	0.5	0%	0.5	A-36
99	Plate ST 10x32.7# Web (0.500) - New - 15% Red.	0.5	15%	0.425	A-36
100	Plate ST 10x32.7# Web (0.500) - Sat. - 25% Red.	0.5	25%	0.375	A-36
101	Plate ST 10x32.7# Web (0.500) - Marg. - 35% Red.	0.5	35%	0.325	A-36
102	Plate ST 10x32.7# Web (0.500) - Unsat. - 50% Red.	0.5	50%	0.25	A-36
103	Plate ST 12x34# Flange (0.582)	0.582	0%	0.582	A-36
104	Plate ST 12x34# Flange (0.582) - Sat. - 25% Red.	0.582	25%	0.4365	A-36

Property No.	Property Name	Thick.	%Reduction	Reduced Thickness	Material
		inches		inches	
105	Plate ST 12x34# Flange (0.582) - Marg. - 35% Red.	0.582	35%	0.3783	A-36
106	Plate ST 12x34# Flange (0.582) - Unsat. - 50% Red.	0.582	50%	0.291	A-36
107	Plate ST 12x34# Web (0.416)	0.416	0%	0.416	A-36
108	Plate ST 12x34# Web (0.416) - Sat. - 25% Red.	0.416	25%	0.312	A-36
109	Plate ST 12x34# Web (0.416) - Marg. - 35% Red.	0.416	35%	0.2704	A-36
110	Plate ST 12x34# Web (0.416) - Unsat. - 50% Red.	0.416	50%	0.208	A-36
111	Plate ST 12x38# Flange (0.682)	0.682	0%	0.682	A-36
112	Plate ST 12x38# Flange (0.682) - Sat. - 25% Red.	0.682	25%	0.5115	A-36
113	Plate ST 12x38# Flange (0.682) - Marg. - 35% Red.	0.682	35%	0.4433	A-36
114	Plate ST 12x38# Flange (0.682) - Unsat. - 50% Red.	0.682	50%	0.341	A-36
115	Plate ST 12x38# Web (0.440)	0.44	0%	0.44	A-36
116	Plate ST 12x38# Web (0.440) - Sat. - 25% Red.	0.44	25%	0.33	A-36
117	Plate ST 12x38# Web (0.440) - Marg. - 35% Red.	0.44	35%	0.286	A-36
118	Plate ST 12x38# Web (0.440) - Unsat. - 50% Red.	0.44	50%	0.22	A-36
119	Plate MC 13x35# Flange (0.61)	0.61	0%	0.61	A-36
120	Plate MC 13x35# Flange (0.61) - Sat. - 25% Red.	0.61	25%	0.4575	A-36
121	Plate MC 13x35# Web (0.447)	0.447	0%	0.447	A-36
122	Plate MC 13x35# Web (0.447) - Sat. - 25% Red.	0.447	25%	0.33525	A-36
123	Plate ST 13.5x42# Flange (0.636)	0.636	0%	0.636	A-36
124	Plate ST 13.5x42# Flange (0.636) - Sat. - 25% Red.	0.636	25%	0.477	A-36
125	Plate ST 13.5x42# Flange (0.636) - Marg. - 35% Red.	0.636	35%	0.4134	A-36
126	Plate ST 13.5x42# Flange (0.636) - Unsat. - 50% Red.	0.636	50%	0.318	A-36
127	Plate ST 13.5x42# Web (0.463)	0.463	0%	0.463	A-36
128	Plate ST 13.5x42# Web (0.463) - Sat. - 25% Red.	0.463	25%	0.34725	A-36

Property No.	Property Name	Thick.	%Reduction	Reduced Thickness	Material
		inches		inches	
129	Plate ST 13.5x42# Web (0.463) - Marg. - 35% Red.	0.463	35%	0.30095	A-36
130	Plate ST 13.5x42# Web (0.463) - Unsat. - 50% Red.	0.463	50%	0.2315	A-36
131	Plate WF 18x96# Flange (0.831)	0.831	0%	0.831	A-36
132	Plate WF 18x96# Flange (0.831) - Sat. - 25% Red.	0.831	25%	0.62325	A-36
133	Plate WF 18x96# Flange (0.831) - Marg. - 35% Red.	0.831	35%	0.54015	A-36
134	Plate WF 18x96# Flange (0.831) - Unsat. - 50% Red.	0.831	50%	0.4155	A-36
135	Plate WF 18x96# Web (0.512)	0.512	0%	0.512	A-36
136	Plate WF 18x96# Web (0.512) - Sat. - 25% Red.	0.512	25%	0.384	A-36
137	Plate WF 18x96# Web (0.512) - Marg. - 35% Red.	0.512	35%	0.3328	A-36
138	Plate WF 18x96# Web (0.512) - Unsat. - 50% Red.	0.512	50%	0.256	A-36
139	Plate WF 24x120# Flange (0.93)	0.93	0%	0.93	A-36
140	Plate WF 24x120# Flange (0.93) - New - 15% Red.	0.93	15%	0.7905	A-36
141	Plate WF 24x120# Flange (0.93) - Sat. - 25% Red.	0.93	25%	0.6975	A-36
142	Plate WF 24x120# Flange (0.93) - Marg. - 35% Red.	0.93	35%	0.6045	A-36
143	Plate WF 24x120# Flange (0.93) - Unsat. - 50% Red.	0.93	50%	0.465	A-36
144	Plate WF 24x120# Web (0.556)	0.556	0%	0.556	A-36
145	Plate WF 24x120# Web (0.556) - New - 15% Red.	0.556	15%	0.4726	A-36
146	Plate WF 24x120# Web (0.556) - Sat. - 25% Red.	0.556	25%	0.417	A-36
147	Plate WF 24x120# Web (0.556) - Marg. - 35% Red.	0.556	35%	0.3614	A-36
148	Plate WF 24x120# Web (0.556) - Unsat. - 50% Red.	0.556	50%	0.278	A-36

Beam Elements

Property No.	Property Name	Depth	Width	Flange Thick.	Web Thick.	% Reduced	Reduced Flange Thick.	Reduced Web Thick.	Material
		inches	inches	inches	inches		inches	inches	
151	Beam ST12WF60 (W24x120)	12.125	12.125	0.9375	0.5625	0%	0.9375	0.5625	A-36
152	Beam ST12WF60 (W24x120) - Sat. - 25% Red.	12.125	12.125	0.9375	0.5625	25%	0.703125	0.421875	A-36
153	Beam ST12WF60 (W24x120) - Marg. - 35% Red.	12.125	12.125	0.9375	0.5625	35%	0.609375	0.365625	A-36
154	Beam ST12WF60 (W24x120) - Unsat. - 50% Red.	12.125	12.125	0.9375	0.5625	50%	0.46875	0.28125	A-36
155	Beam ST12WF55 (W24x110)	12.0625	12	0.875	0.5	0%	0.875	0.5	A-36
156	Beam ST12WF55 (W24x110) - Sat. - 25% Red.	12.0625	12	0.875	0.5	25%	0.65625	0.375	A-36
157	Beam ST12WF55 (W24x110) - Marg. - 35% Red.	12.0625	12	0.875	0.5	35%	0.56875	0.325	A-36
158	Beam ST12WF55 (W24x110) - Unsat. - 50% Red.	12.0625	12	0.875	0.5	50%	0.4375	0.25	A-36
159	Beam ST9WF42.5 (18W85)	9.1875	8.875	0.9375	0.5	0%	0.9375	0.5	A-36
160	Beam ST9WF42.5 (18W85) - Sat. - 25% Red.	9.1875	8.875	0.9375	0.5	25%	0.703125	0.375	A-36
161	Beam ST9WF42.5 (18W85) - Marg. - 35% Red.	9.1875	8.875	0.9375	0.5	35%	0.609375	0.325	A-36
162	Beam ST9WF42.5 (18W85) - Unsat. - 50% Red.	9.1875	8.875	0.9375	0.5	50%	0.46875	0.25	A-36
163	Beam ST8WF32 (W24x110)	8	8.5	0.6875	0.4375	0%	0.6875	0.4375	A-36
164	Beam ST8WF32 (W24x110) - Sat. - 25% Red.	8	8.5	0.6875	0.4375	25%	0.515625	0.328125	A-36
165	Beam ST8WF32 (W24x110) - Marg. - 35% Red.	8	8.5	0.6875	0.4375	35%	0.446875	0.284375	A-36
166	Beam ST8WF32 (W24x110) - Unsat. - 50% Red.	8	8.5	0.6875	0.4375	50%	0.34375	0.21875	A-36
167	Beam T (W24x131)	24.48	12.855	0.96	0.605	0%	0.96	0.605	A-36

Appendix B – Dry Dock No. 2 Lightship Weight Calculation

Table of Contents

TITLE: Weight Estimate

SHIP: BAE SF - DD #2

Plan No.

Section:

Frames:

WT Grp:

BRUCE S. ROSENBLATT & ASSOCIATES, LLC

NAVAL ARCHITECTS & MARINE ENGINEERS

OAKLAND OFFICE

ESTIMATE OF WEIGHT

SHEET No. 1 of 1

BSR CONT: 1043.005

DATE: 8/29/2012

Piece No.	Description, Material, Dimensions	Remarks	Weight (LT)	Abv Baseline Vert CG (ft)	Abv Baseline Vert Mom (ft-LT)	Ref to Fr 0 - South + North (ft)	Ref to Fr 0 Long Mom (ft-LT)	Ref to CL + West - East (ft)	Ref to CL Transv Mom (ft-LT)
	Lightship Basis	Ref. EBDG Report 08003-001-843-4B	18329.27	25.00	458232	400.00	7331708		0.00
	Removal - Temporary Crane	Ref. EBDG Report 08003-001-843-4B	-71.43	89.00	-6357	400.00	-28572		0.00
	New East Crane	*VCG assumed 20ft above crane rails	450.00	89.00	40050	400.00	180000		0.00
	Transformer - Safety Deck West	*VCG assumed 3ft above safety deck	8.93	61.50	549	400.00	3571		0.00
	Transformer - Safety Deck East	*VCG assumed 3ft above safety deck	8.93	61.50	549	400.00	3571		0.00
	Sponsons - (6x)	Ref. EBDG Report 08003-001-843-4B	185.00	25.50	4718	400.00	74000		0.00
	Doubler Plate - Existing (36,900)	Ref. EBDG Report 08003-001-843-4B	-366.00	20.75	-7595	400.00	-146400		0.00
	Doubler Plate - Total (79,200)	Ref. DWG DD2 2012 Pontoon Deck Repairs	723.00	20.75	15002	400.00	289200		0.00
		A. Romanczuk - 06-25-2012							
	LIGHTSHIP TOTAL		**19267.70**	**26.22**	**505148**	**400.00**	**7707079**	**0.00**	**0.00**

Notes:
1. This lightship weight calculation is solely for the purpose of determining the drydock weight for loading the drydock in FEA Structural Model.
2. VCG data are approximations and may not accurately reflect the stability characteristics of the drydock.
3. LCG of drydock is assumed to be at 400ft North of Frame 0.
4. Reference data from EBDG Report 08003-001-843-4B and meeting with A. Romanczuk on 08/23/2012.

Estimated By: A Lachtman

Checked By: D Smith

Reviewed by: ________

Appendix C – Dry Dock No. 2 Corrosion Properties

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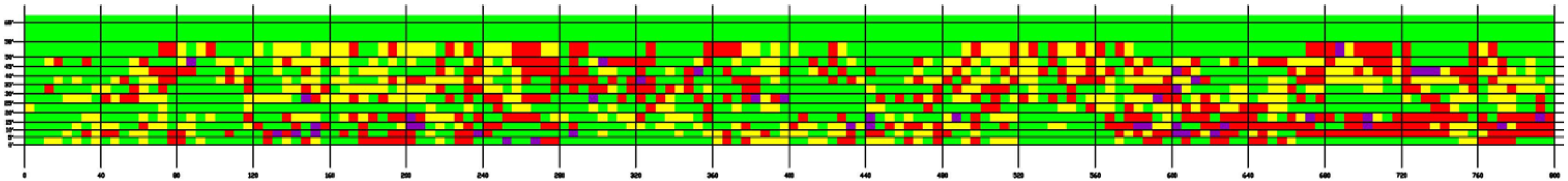
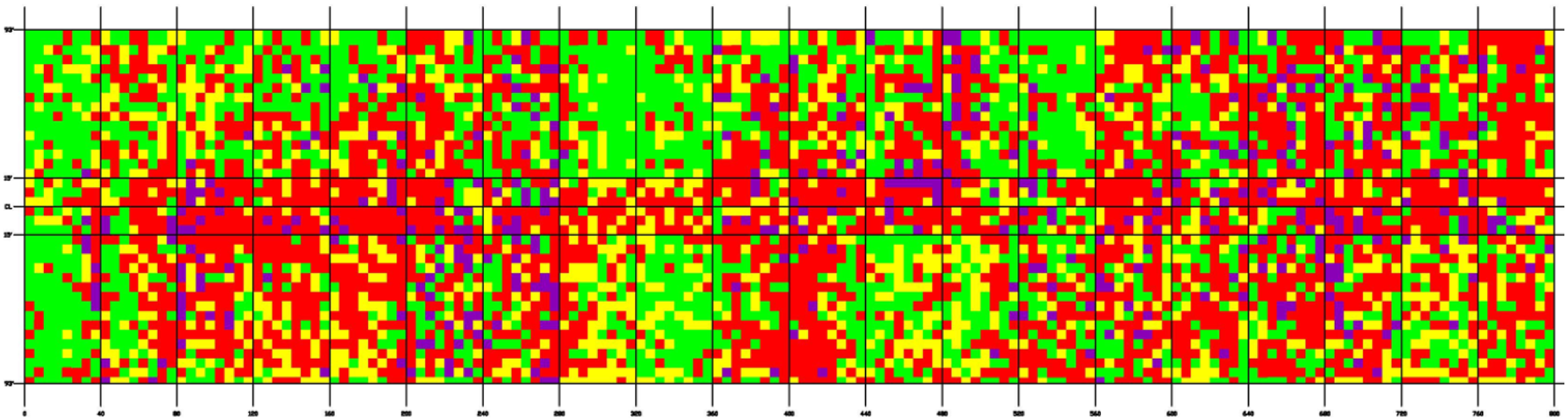
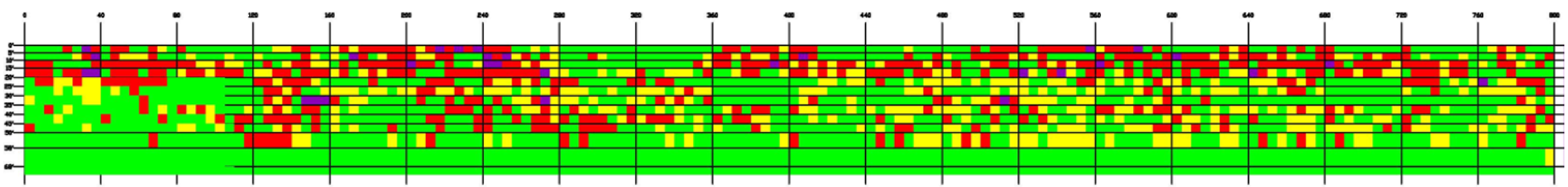
Dry Dock No. 2 Corrosion Properties – Bottom Plating – As-Measured



WINGWALL EXTERIOR - WEST

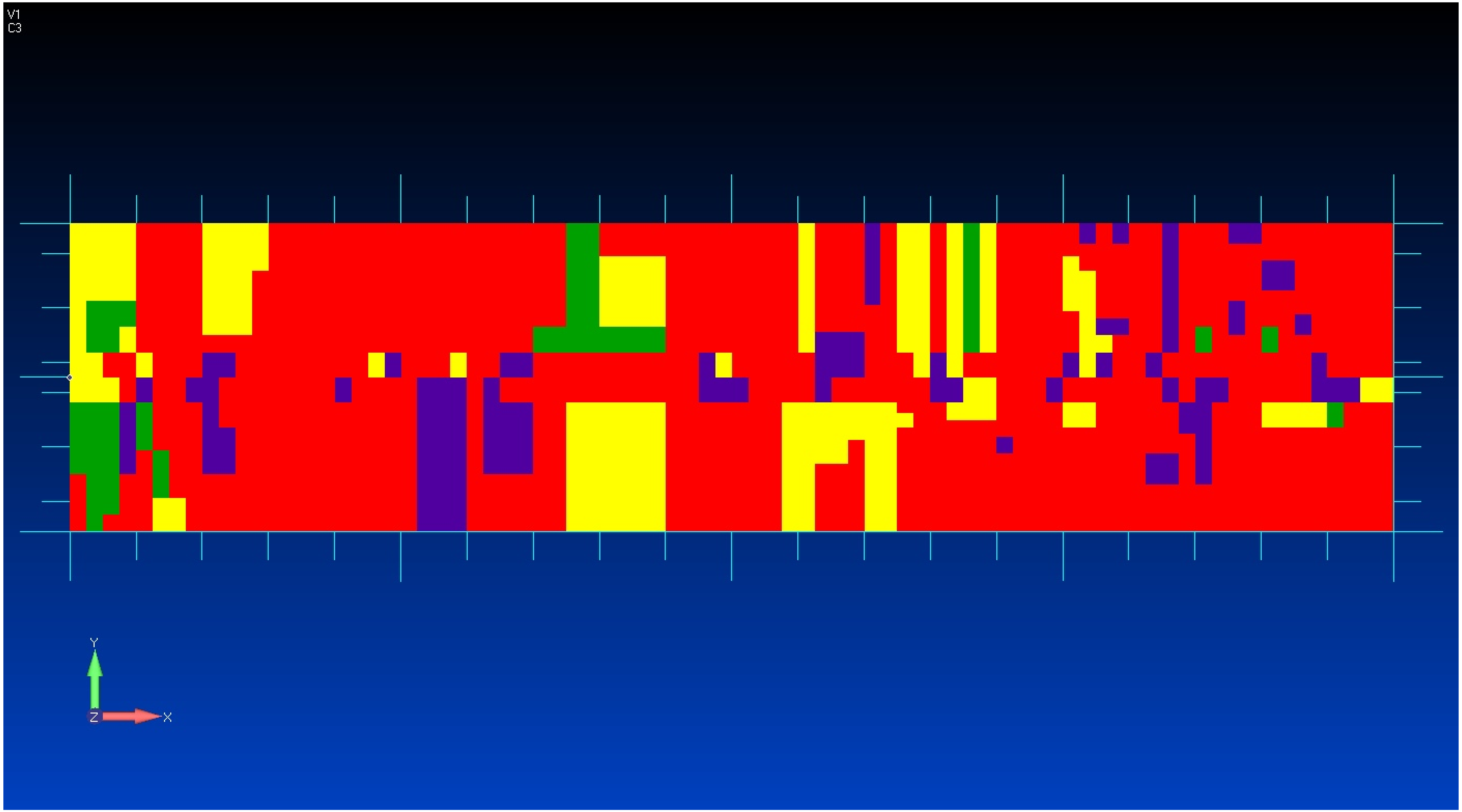


BOTTOM PLATE

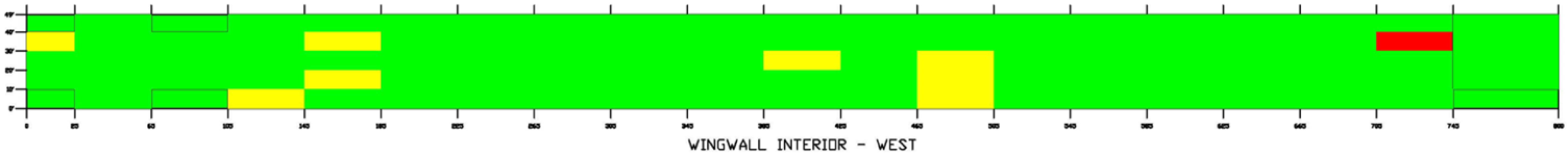


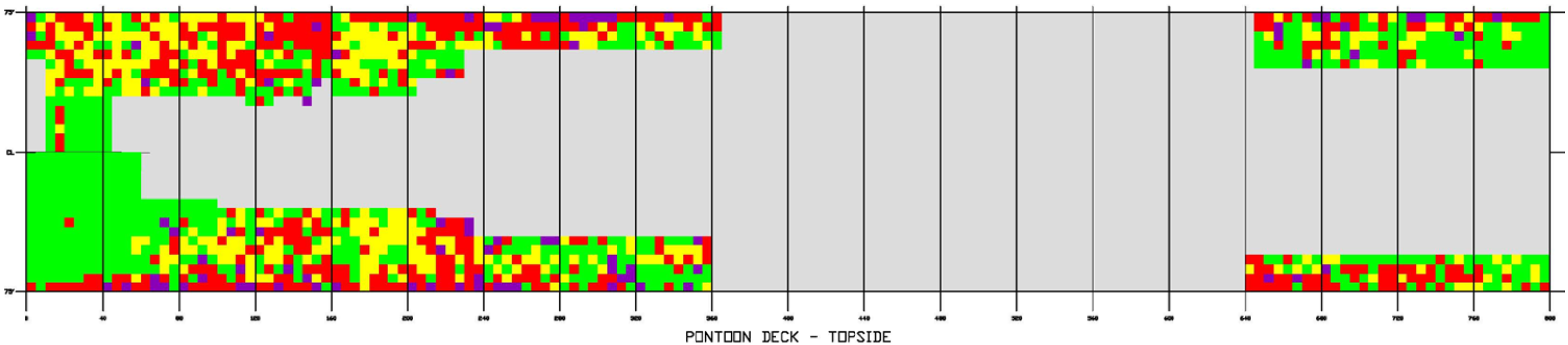
WINGWALL EXTERIOR - EAST

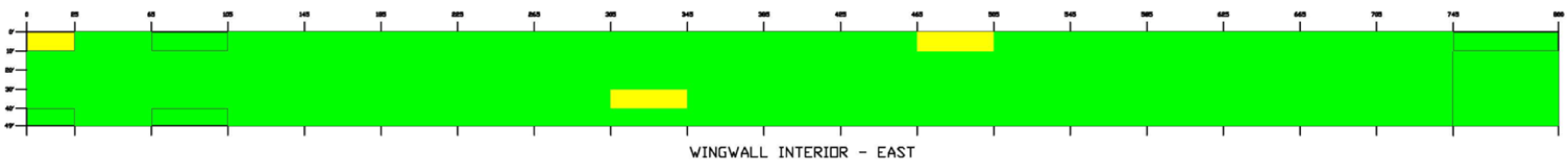
Dry Dock No. 2 Corrosion Properties – Bottom Plating – As-Modeled



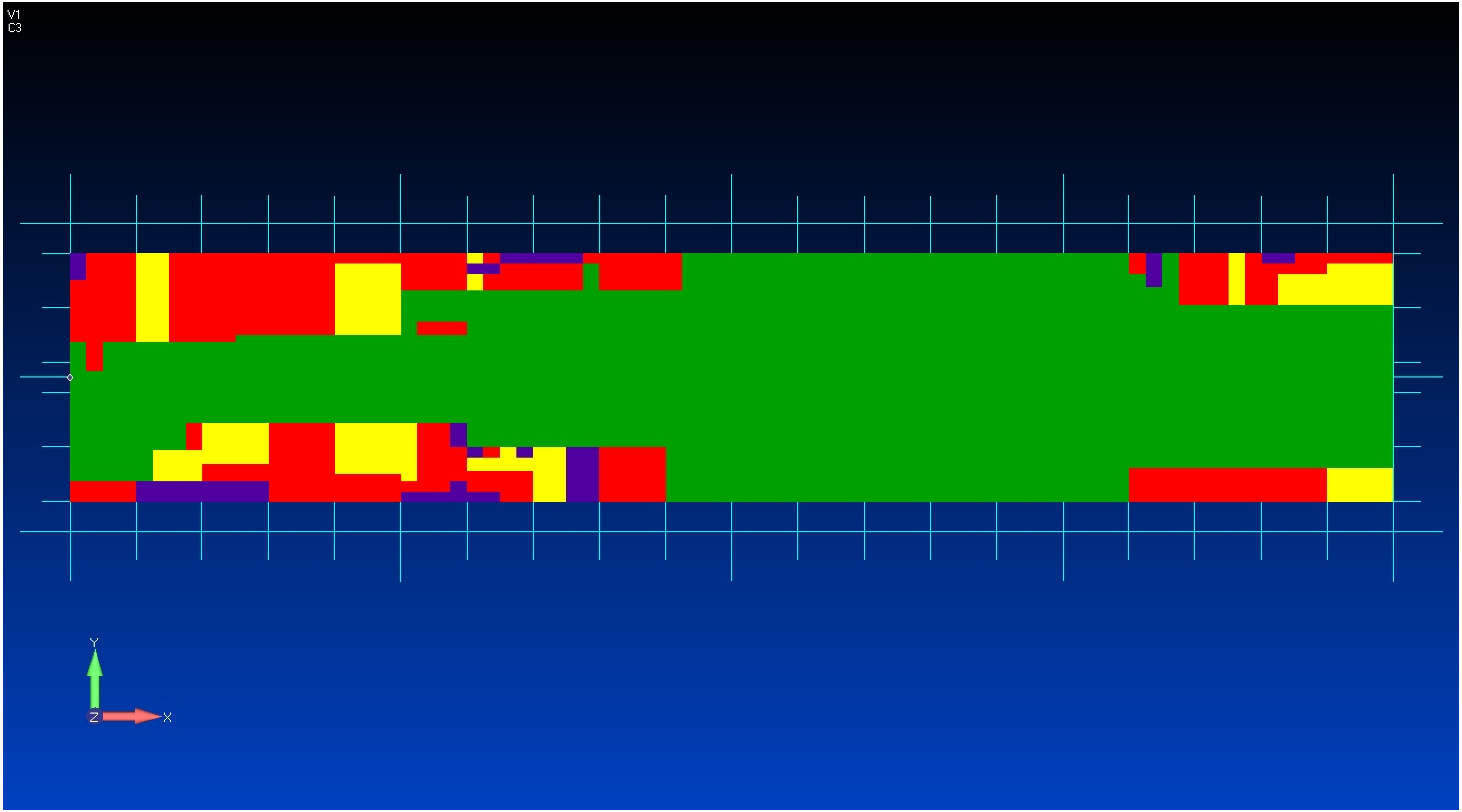
Dry Dock No. 2 Corrosion Properties – Pontoon Deck Plating – As-Measured



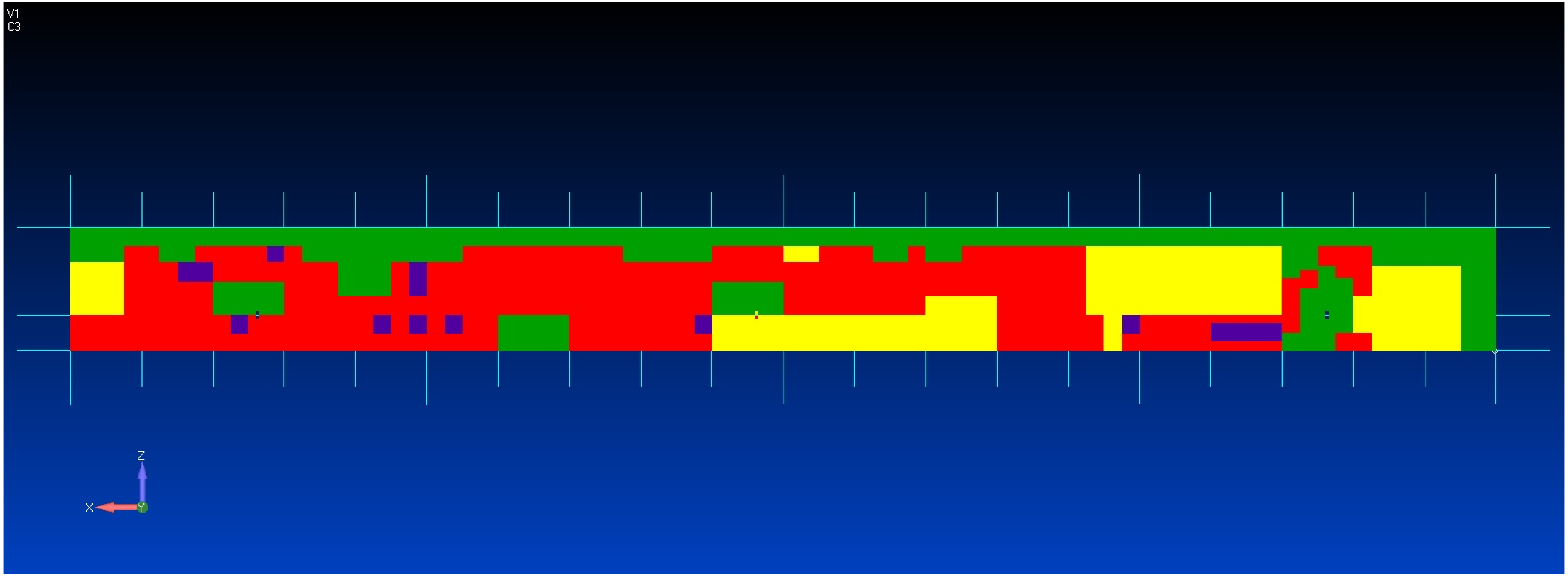




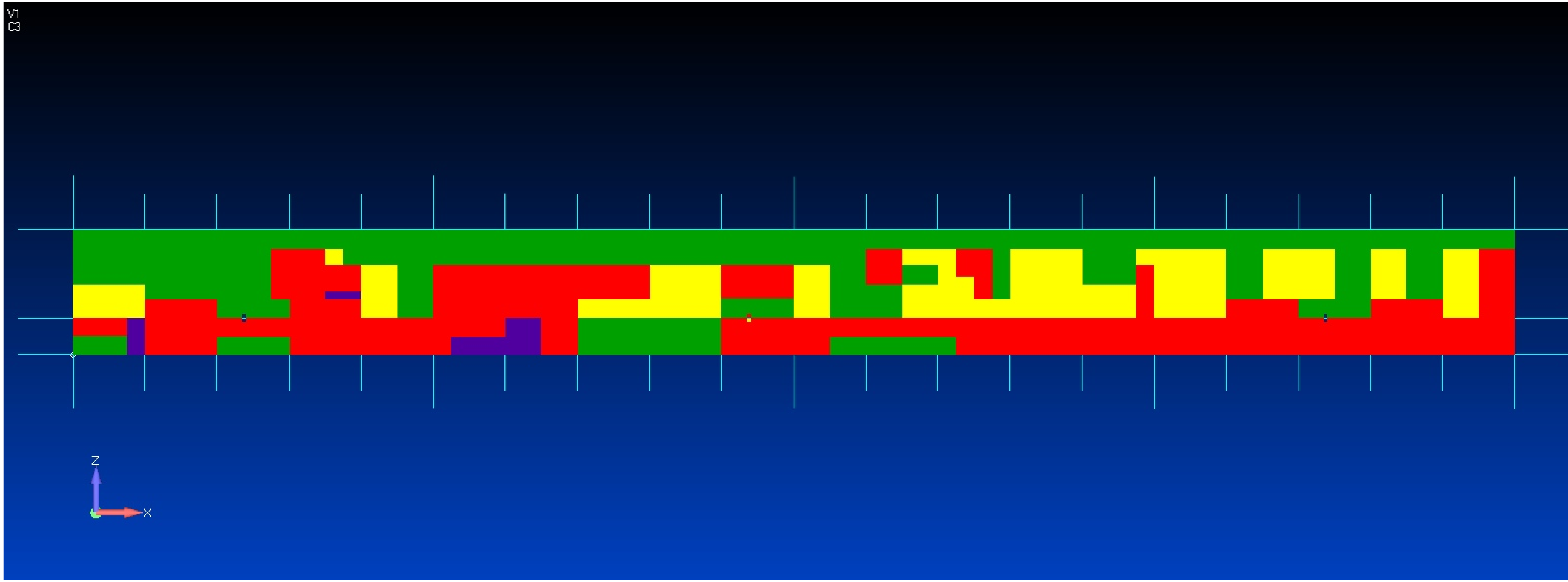
Dry Dock No. 2 Corrosion Properties – Pontoon Deck Plating – As-Modeled



Dry Dock No. 2 Corrosion Properties – Outbd Wingwall Port Plating – As-Modeled



Dry Dock No. 2 Corrosion Properties – Outbd Wingwall Stbd Plating – As-Modeled



Appendix D – Dry Dock No. 2 Lifting Capacity

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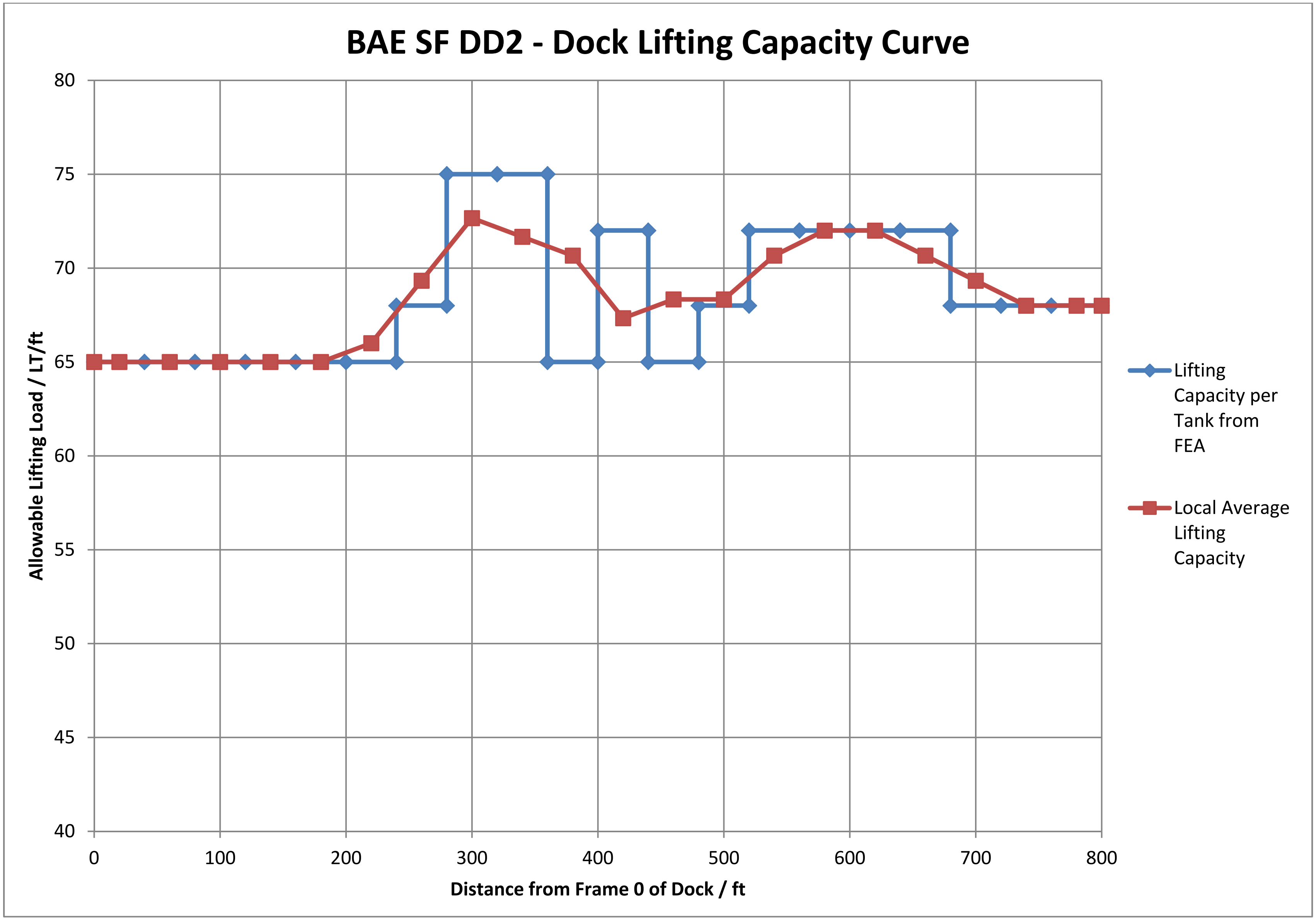
Appendix D – Dry Dock No. 2 Lifting Capacity

Maximum Allowable Loading

Frames	Tanks	Load	Load per Tank	Max. A-36 Stress	Max. Mayari-R Stress	Average Load
		LT/ft	LT	psi	psi	LT/ft
0 to 4	1 & 2	65	2600			65.00
4 to 8	3 & 4	65	2600	34958	36677	65.00
8 to 12	5 & 6	65	2600	35226	36712	65.00
12 to 16	7 & 8	65	2600	32746	34978	65.00
16 to 20	9 & 10	65	2600	32363	35064	65.00
20 to 24	11 & 12	65	2600	33326	40516	66.00
24 to 28	13 & 14	68	2720	33327	39384	69.33
28 to 32	15 & 16	75	3000	32902	41835	72.67
32 to 36	17 & 18	75	3000	32698	38160	71.67
36 to 40	19 & 20	65	2600	34054	36887	70.67
40 to 44	21 & 22	72	2880	32365	42136	67.33
44 to 48	23 & 24	65	2600	35909	37937	68.33
48 to 52	25 & 26	68	2720	33722	43299	68.33
52 to 56	27 & 28	72	2880	34609	38962	70.67
56 to 60	29 & 30	72	2880	32627	37647	72.00
60 to 64	31 & 32	72	2880	33003	42488	72.00
64 to 68	33 & 34	72	2880	33251	43097	70.67
68 to 72	35 & 36	68	2720	32219	39783	69.33
72 to 76	37 & 38	68	2720	30505	39469	68.00
76 to 80	39 & 40	68	2720			68.00

Total 54800 LT


BAE SF DD2 - Dock Lifting Capacity Curve
Allowable Lifting Load / LT/ft
80
75
70
65
60
55
50
45
40
0
100
200
300
400
500
600
700
800
Distance from Frame 0 of Dock / ft
Lifting Capacity per Tank from FEA
Local Average Lifting Capacity