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DRY DOCK NO. 2 – ANALYSIS OF WINGWALL SHELL PLATE AS SURVEYED THICKNESSES

Prepared for

BAE SYSTEMS
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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 dry dock is subject to periodic certifications and the most recent report by Heger Dry Dock, Inc. (HEGER), Reference 1, dated December 7, 2016, expressed HEGER's concern that the dock's current structural condition has severely corroded shell plating, with number of holed-through areas. The holes, located throughout the dock, impede the watertight integrity of numerous ballast tanks and raise the following concerns:

1. The dock cannot hold draft without operating pumps to offset the leaking of ballast tanks. This was confirmed and observed in HEGER's submergence test conducted in the 2016 control inspection.

2. The holed-through plating creates local hydrostatic strength deficiencies which put corroded areas of the dock at risk of failure. Due to lack of material strength, there is the potential for these holes to enlarge significantly during a docking evolution, to a point where the amount of external leakage cannot be offset by the dock's pumps. It should also be noted that the dock does not have emergency cross-connect values in the event an individual tank's pump is lost, thus losing the ability to offset external leakage.

The areas of concern are the shell plating of both the East and West wingwalls. This plating has been surveyed by ultrasonic thickness measurements (UT) and the results of these surveys have been accumulated in spreadsheet by the BAE dockmaster.

The purpose of this analysis is to determine if the current steel thicknesses as surveyed can competently support the dockings currently planned. As such shell plating panels are analyzed for the stress resulting from the head pressures required to dry dock the *USNS Carl Brashear*. We considered "strip theory" where a narrow strip of shell plating is analyzed as a fixed end beam subject to a continuous load developed from the head pressure. We find that the deflections invalidated this simplistic analysis and opted to finite element analysis to a typical shell plate panel, which considers membrane stress and reports the results of the analysis using von Mises stresses.

We need to emphasize that the steel gauging is crucial to the performance of this task. This service provides a small sample of the measured thickness of the steel, which then must be extrapolated to the dry dock. It is not feasible to gauge all areas as the service is expensive and takes time.

A typical shell plate panel in the area of concern is 120 in. x 25 in. As built the steel plate was ASTM A36 steel that was 7/16 in. thick. The UT findings report significant wastage in many places. We opted to assume a thickness of 0.25 in. for these analyses. We reviewed the docking plan for the *USNS Carl Brashear* and found that four head pressures up to various drafts summarized the use of the dock. The maximum von Mises stress was calculated by FEA for each of the head pressures. This became the basis for determining the stress associated with each UT reading because the stress varies inversely with the ratio of the thicknesses squared. If the UT reported was 0.125 in. (and there were some) then the maximum stress for this panel will be 4 times that of the stress for a 0.25 in. thick panel. The problem with these assumptions as that UT measurements are localized and do not provide good assessment of steel thickness throughout the entire panel.

Results

The dock is constructed of A-36 steel with swaths of Mayari-R steel in key areas elsewhere in the dry dock. A-36 steel is ordinary steel with a yield strength of 36,000 psi. The original calculations assumed allowable stresses of 60% of yield. When performing FEA, it is realistic to assume a higher allowable stress depending on mesh size. Recently published ABS guidance for FEA, Reference 3, permits an allowable stress of up to 1.25 times yield stress in small areas as a function of mesh size and subject to other considerations. It was decided that we should note all stresses that exceed yield stress and take action on all stresses that exceed. 1.25 times yield stress. This action was to require three more UT readings within 2 ft. of the original reading. These three readings were averaged and the stresses were updated for the new thickness. There were 16 locations on the West wingwall and 25 locations on the East wingwall where this was done. In all cases the stresses were reduced to an acceptable level, because, in spite of significant local wastage, there is still adequate steel in the shell to withstand the required head. The dry dock can safely dry dock the *USNS Carl Brashear*.

HEGER's concerns should not be dismissed. We have been able to document that there is more steel thickness remaining in the shell in areas that drew our concern. However, there is still the issue of significant wastage and holes in the dock. During the course of this task we talked about leakage overwhelming the pumps. This is a real concern that needs to be addressed. Finding that there is more overall steel may change the dynamics of patching versus renewing the steel, which is a decision the operator has to make.

The heads selected to perform this analysis were selected in response to a specific ship's dry docking. Since the action taken in response to the initial findings of this analysis documented greater steel thicknesses remaining, the head selected are not limits that are to be absolutely respected. We are aware that normal dry docking cycles have variances in the heads as planned, which are acceptable in the order of +10%.

References

1. Heger Dry Dock Co. Report: 16-87L, "Request for HEGER Certification of Dry Dock No. 2 located in BAE San Francisco, CA", for BAE Systems, Inc., San Francisco. December 7, 2016.
2. DRS Marine INC. Report: Dry Dock 2 Ultrasonic Thickness Inspection Prepared For BAE Systems San Francisco. December 2016.
3. ABS: "Technical Guidance for the Review of Finite Element Analyses".
4. Excel Spreadsheet: "DRS UTS von Mises Wing Walls 20161223 "
5. Excel Spreadsheet: "DRS UTS von Mises Wing Walls 20161230 "

Finite Element Analysis

The finite element model is a 0.25 in. thick steel panel measuring 120 in. x 25 in. Mesh size is 2 in., which is less than 1/10th of the longitudinal frame spacing. This panel has fixed constraints at the nodes all around the perimeter. Load cases were developed for pressure on the elements resulting from sea water heads of 20 ft., 18 ft., 15 Ft. and 11 ft., respectively

The load cases resulting in the following maximum deflections and von Mises stress in the panels:

Table 1 – Global Model Load Cases

Load Case	Sea Water Head ft.	Maximum Deflection in.	Maximum von Mises Stress psi
1	20	0.212	30,807
2	18	0.191	27,726
3	15	0.159	23,105
4	11	0.117	16,944

The following four figures show the von Mises stress contours for each of the four load cases with a criteria stress of 45,000 psi. The maximum deflection occurs in the center of the panel and the maximum stress occurs along the long edges. Panels that are overstressed will show a yielding along the longitudinal frame.

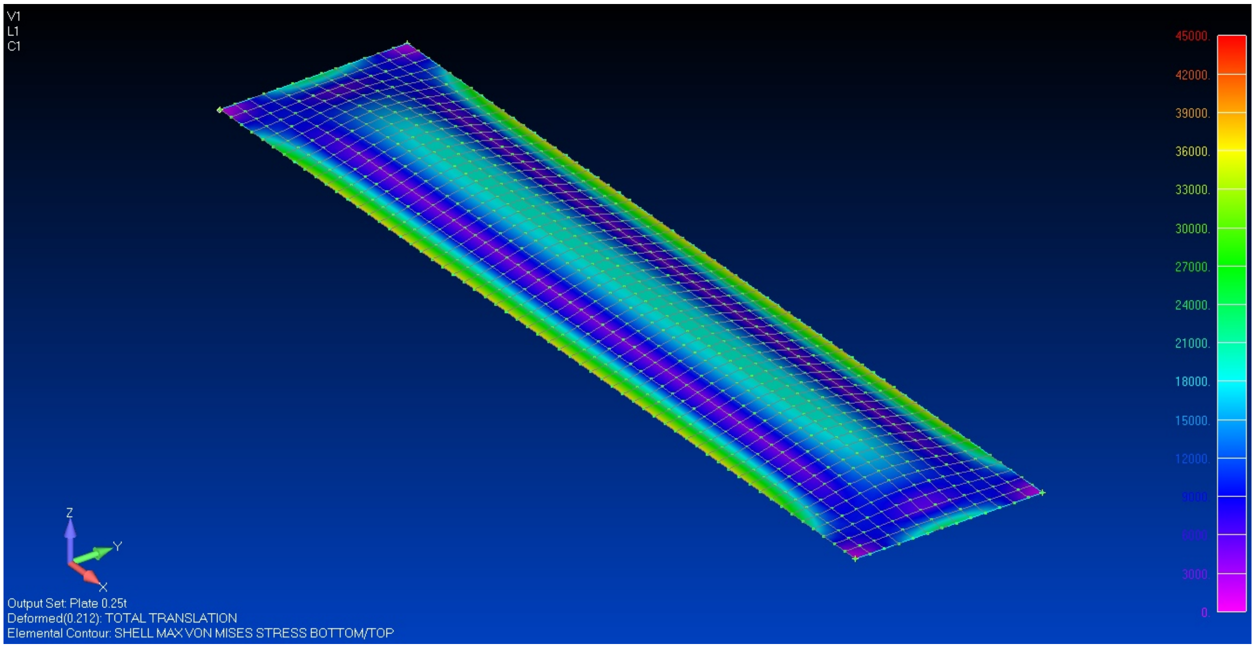

Figure 1 – 20 ft. Head – Shell Plate Panel – 45,000 psi Criteria

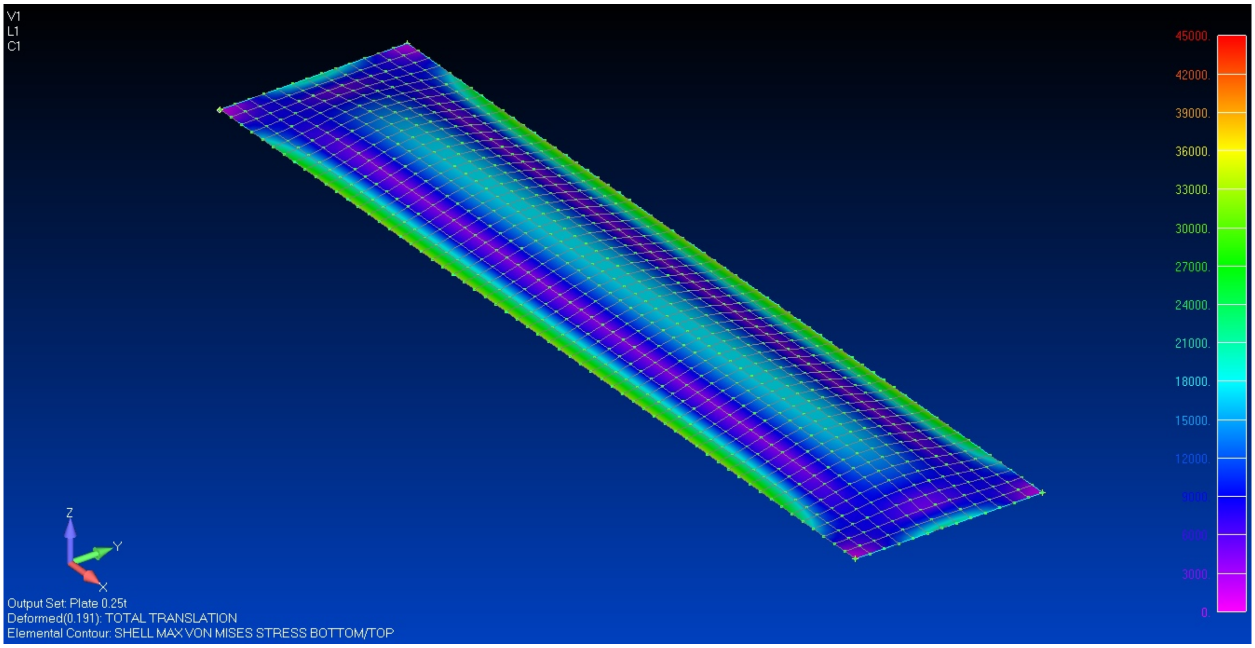

Figure 2 – 18 ft. Head – Shell Plate Panel – 45,000 psi Criteria

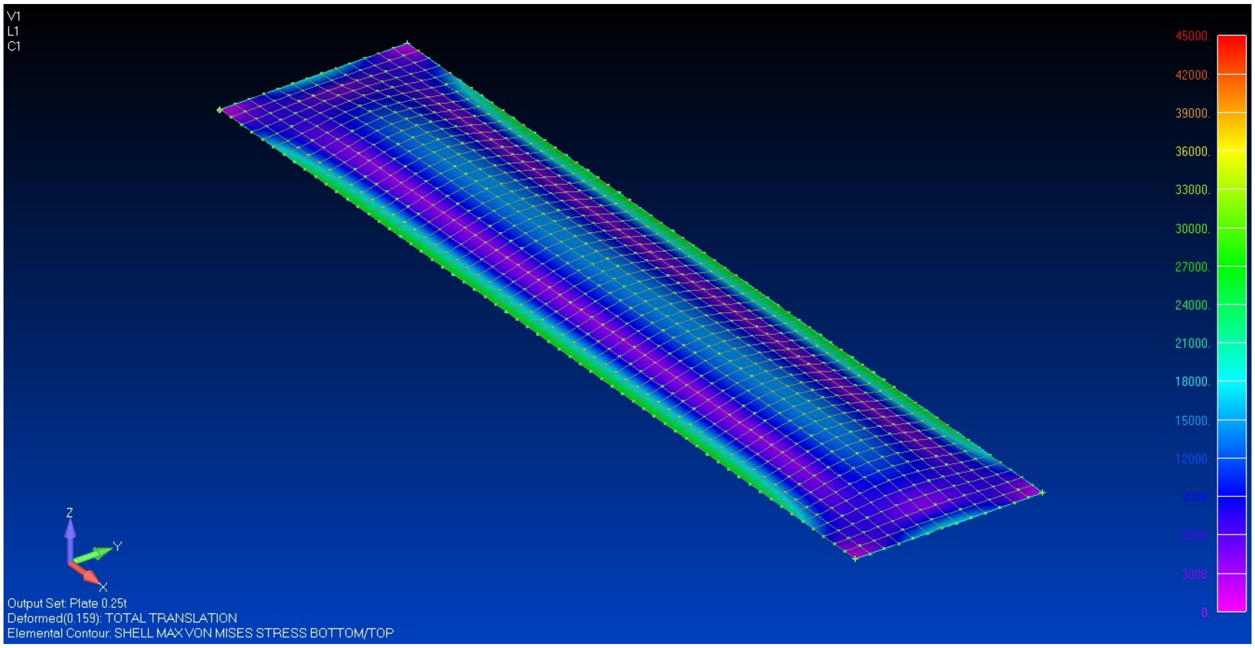

Figure 3 – 15 ft. Head – Shell Plate Panel – 45,000 psi Criteria

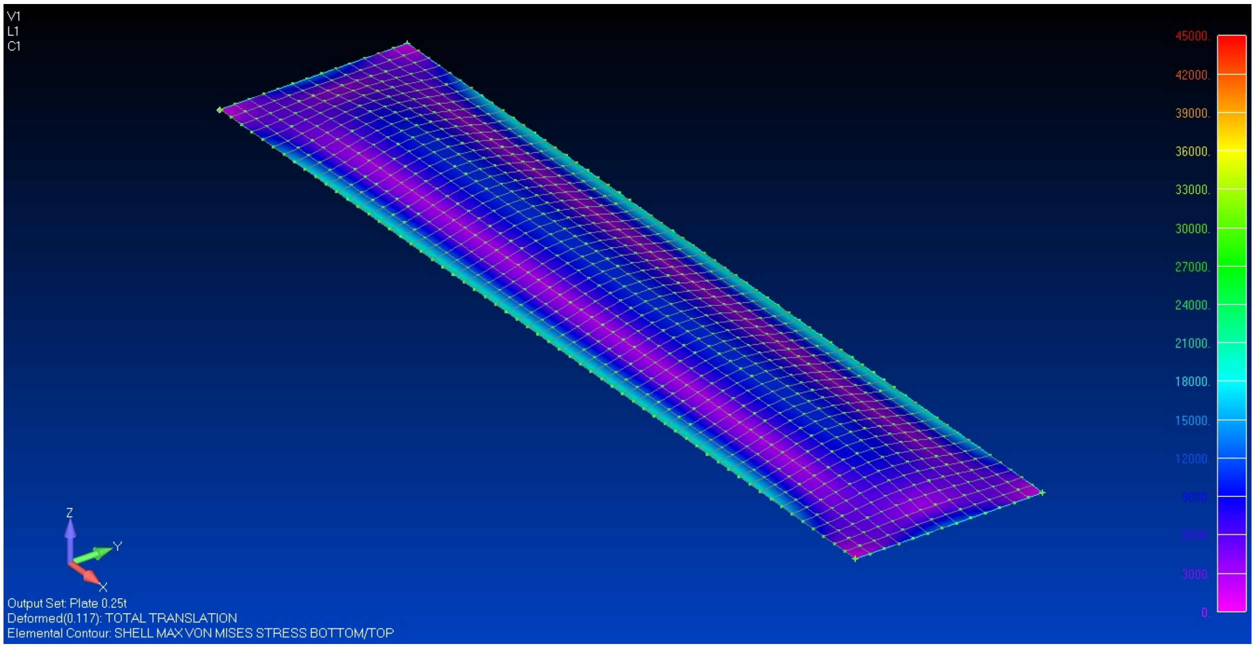

Figure 4 – 11 ft. Head – Shell Plate Panel – 45,000 psi Criteria

Application of Stress Levels to the UT measurements

The spreadsheet that provided the UT measurements was edited to incorporate worksheets that performed this calculation as a function of the measured thicknesses. Thicknesses below the level of 6 ft. ABL were not examined because these UT's are stated to be unreliable. The bottom row of the worksheets reporting stresses is annotated "18 ft Head up to 30 ft draft" or the like. This describes the head pressure considered and for height ABL for where this head is applicable. Note that head level increases with the submergence from draft down to where the water level is in the tank. Head pressure is constant below the tank level height. There were 16 locations on the West wingwall and 25 locations on the East wingwall where the stress level exceeded the criteria of 45,000 psi. The spreadsheet, Reference 4 was submitted to BAE along with recommended action was to require three more UT readings within 2 ft. of the original reading. These three readings were averaged and the stresses were updated for the new thickness. Reference 5 documents that in all cases the stresses were reduced to an acceptable level. Actually a couple of locations that exceeded the stress criteria were overlooked. But the results of the resurvey so overwhelmingly resolved the high stress issues that we are confident that this is not an issue. The dry dock can safely dry dock the USNS Carl Brashear.