Streamlining Shipyard Rigging Analysis

Oct 2011

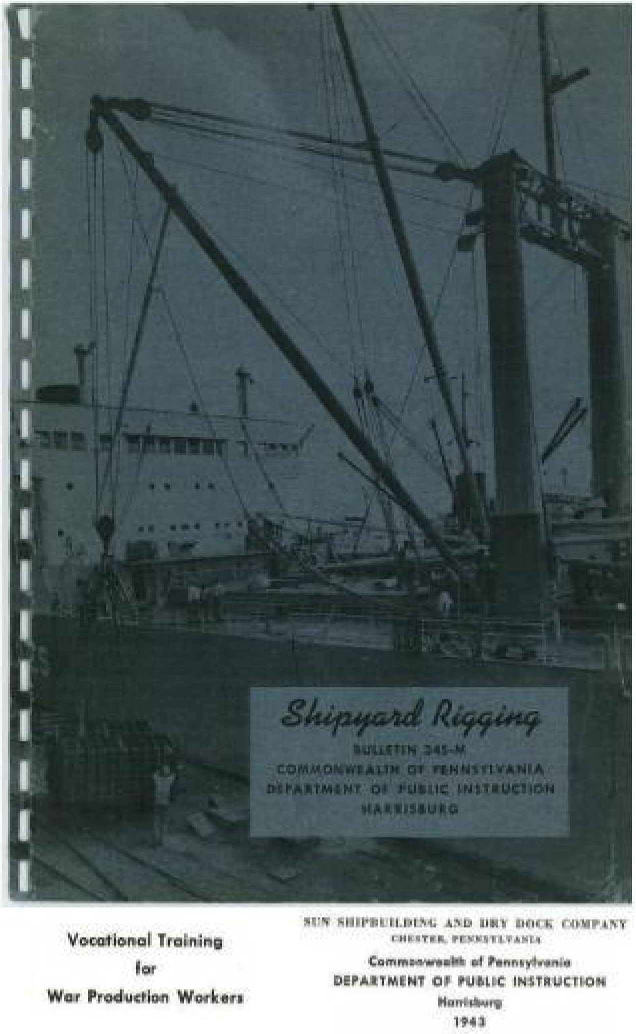
Ship Production Process Technology Panel

What is Shipyard Rigging?

Shipyard rigging involves the lifting, handling, and transportation of partially built structure, which is desired to be as massive as possible, that will undergo temporary loading conditions through orientations that may never occur again, for which the consequences of failure are severe.

References and Guidance

- The Primary Goal is to Create Reference Material to Guide Shipyard Rigging Engineers on Proper Analysis of Lifted Ship Structure
  - Safety
    - Defining the Problem, and its Variables Results in a Greater Likelihood of a Successful Lift
  - Training
    - Having Relevant Reference Material Increases the Versatility of Engineers
  - Cost
    - Greater Understanding Will Lead to More Efficient Solutions, and a Reduction of Overly Conservative Designs



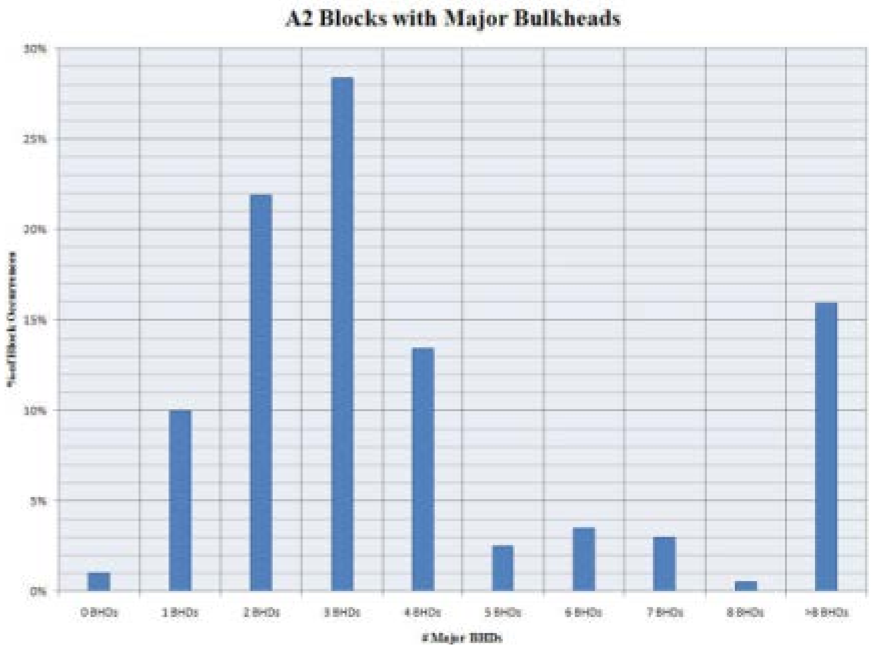
GENERAL DYNAMICS
NASSCO

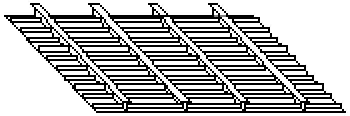
Improving Rigging Analysis

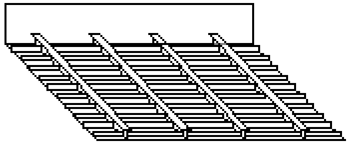
- Lifted Structure Analysis
  - What Type of Block are Lifted?
    - Weight, Shape, Size, Rigidity
  - What Loads are Expected?
    - Total Weight
    - Center of Gravity
    - Dynamic Loads
    - Operational Factors
  - How can one Analyze it?
    - Classic Sectional Analysis
    - Simplified and Detailed FEA
  - How Accurate are we?
    - Strain Gauges, Accelerometers
  - Appropriate Design Factor
    - Safety and Cost

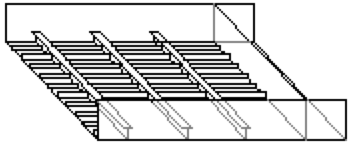
Typical Small Block Types

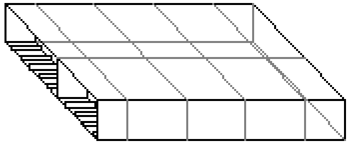
- Cataloging Standard Block Types
  - Rigidity of Object Lifted can be a Concern
    - Function of Number of Significant Bulkheads
    - Function of Member Size.
  - Most Small Blocks Have at Least One Bulkhead
    - Over Half Have Two or Three Bulkheads





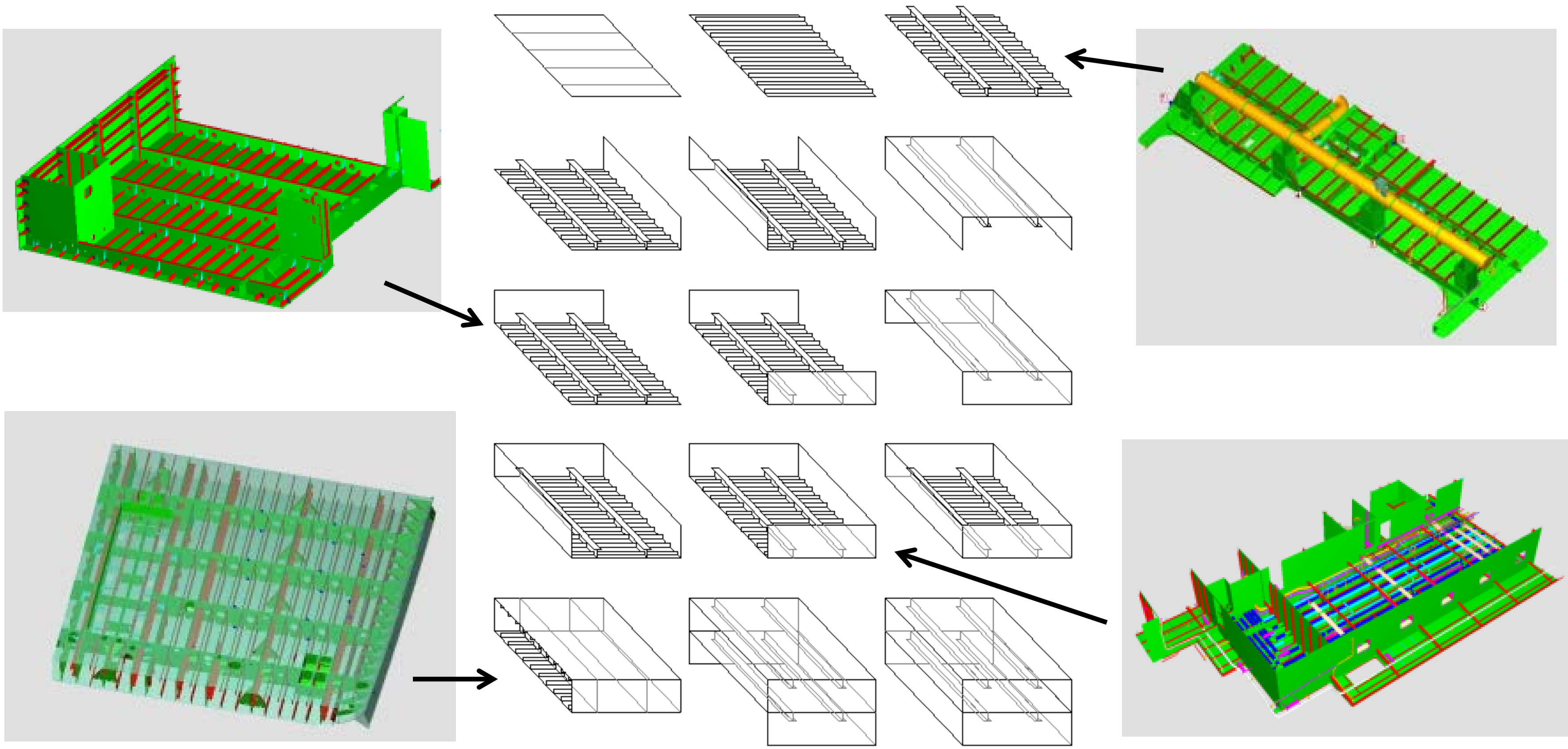






Typical Small Block Types

- Review and Analysis Conducted on Common Block Types to Maximize the Benefit of Information Created



Four Blocks Lifted and Analyzed to Date

Deck Block with Shell
- June 7th ,17th 2010
- Dec 8th 2010
- 82 - 96 Short Ton
- 53' x 52' x 14'
- 7% - 28% Outfitting
- One Bulkhead

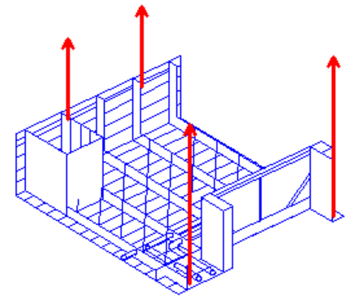
Frame Stiffened Panel
- August 12th 2011
- 44 Short Tons
- 66' x 20' x 8'
- 34% Outfitting
- No Bulkheads

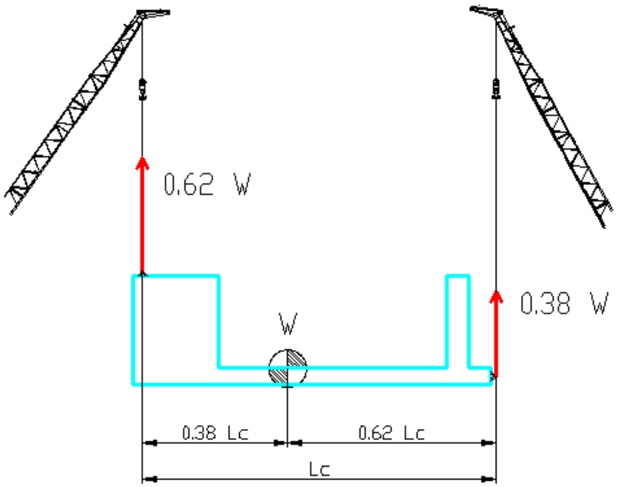
Inner Bottom
- March 28th 2011
- 212 Short Tons
- 61' x 51' x 7'
- 5% Outfitting
- Very Rigid
- 13 Bulkheads

Small House Block
- April 11th 2011
- 44 Short Tons
- 77' x 38' x 10'
- 18% Outfitting
- Flexible
- Four Bulkheads

Typical Rigging Analysis

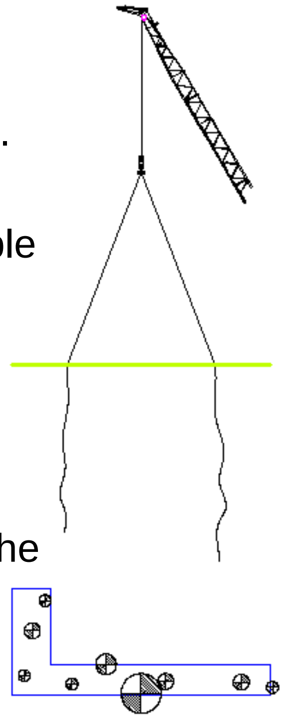
- Rigging Analysis Involves Estimating or Calculating:
  - Weight and COG
    - Steel, Outfit, Free Ride, Temporary Structure.
  - Determination of General Lifting Arrangement
  - Estimating Division of Sling Forces
    - Free Body Diagram of Lifted Object with Assumptions of Rigidity, Quasi-Static Condition and a Statically Determinate Arrangement.
  - Structural Analysis
    - Selection of Padeye,
    - Global Structure,
    - Local Structure





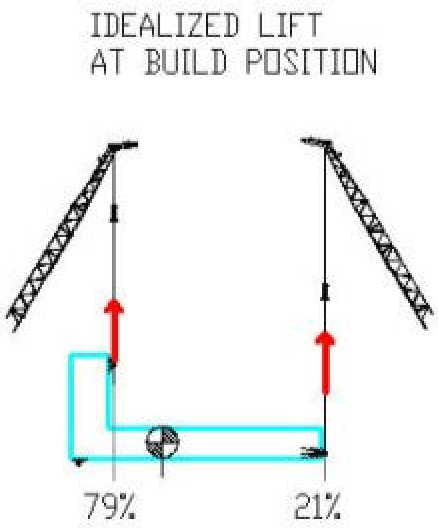
Estimating Variable Weight

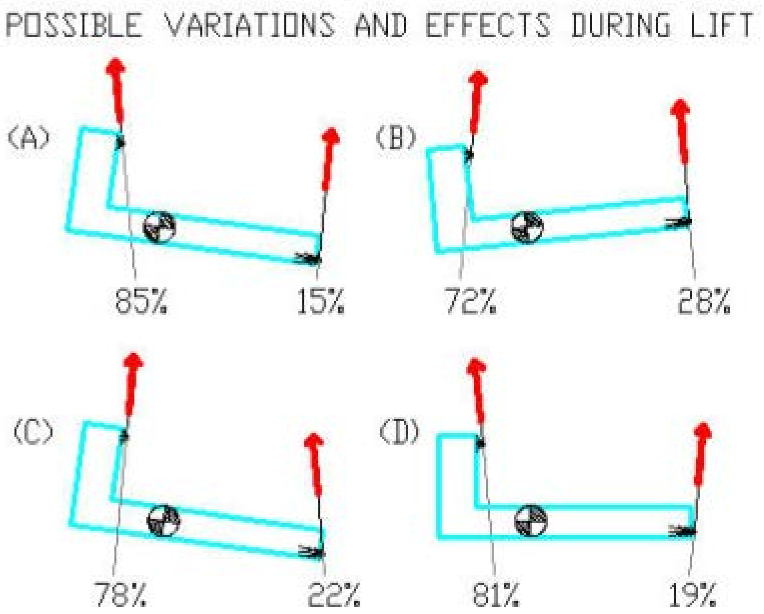
- The Fundamental Rigging Estimate, Lifted Weight and COG
  - Estimated Weight
    - Steel: Usually 60% to 90% of Block Weight, Homogenous Solid, Easiest to Estimate.
    - Outfitting: More Difficult to Estimate Weight and Installation Location. Estimates Greatly Affected by Missing or Added Parts
    - Free Ride: Yet to be Installed, in Wrong Location, Tool Boxes, Variable and Possibly Higher Weight Than Estimated
    - Temporary Parts: Padeyes, Strong Backs, Braces, Fittings
    - Rigging Gear: Crane sees Weight, but Minimal Affect on Block
  - Estimated Center Of Gravity (COG)
    - Compensating Errors: The Whole is Equal to the Statistical Sum of the Parts.
  - Weight Distribution
    - Flexible Block: Non-Rigid Body, Can Effect Load Path and Individual Sling Loading



Operational Variables

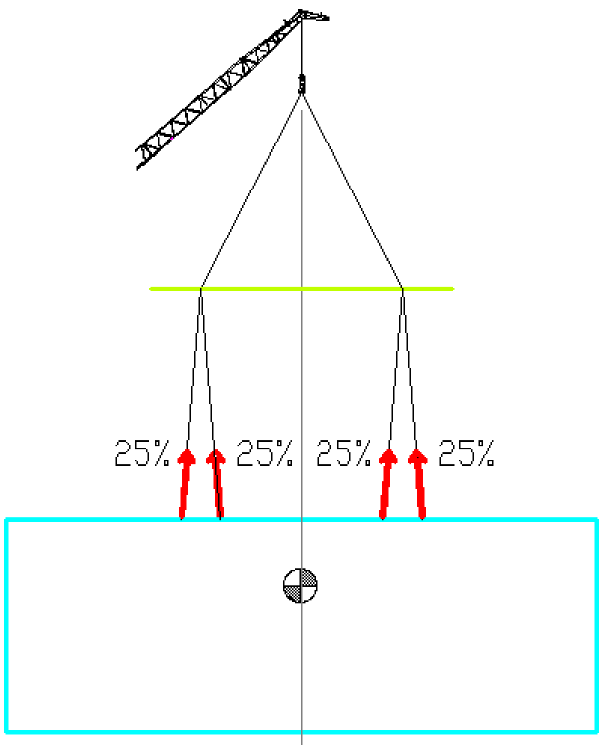
- Lift Specific Factors Can Heavily Influence Loads and Stresses
  - Slings: Exact Length Will Affect Angle, Elasticity, Load sharing
  - Cranes: Travel Speed, Winch Speed, Separation Distance, Block Orientation
  - Spreader bar: Exact Spread Will Affect Angles, Loads
  - Weight: What Exactly is on Block, Center of Gravity
  - Weather: Wind, Rain Water

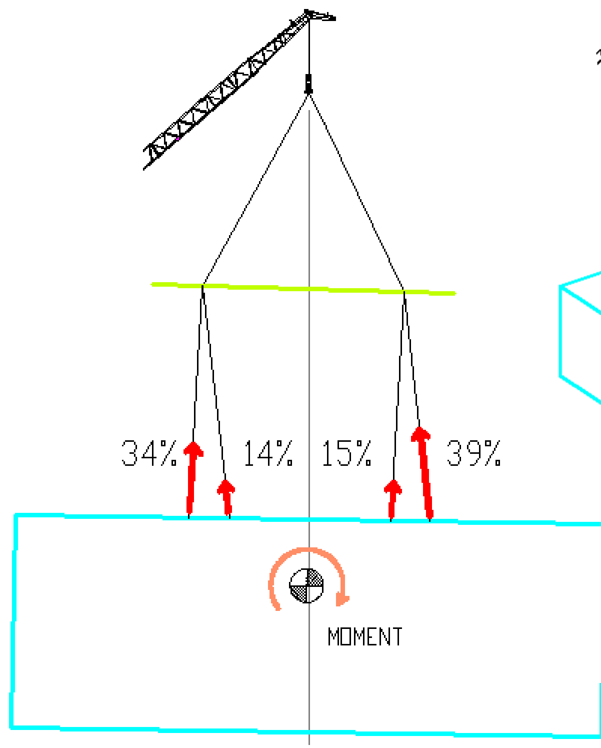


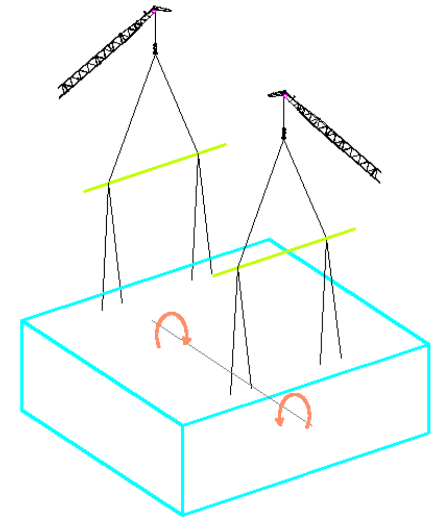


Operational Variables

- Statically Indeterminate Lift Geometry
  - <u>Slings</u>: Exact Length and Elasticity Will Affect Load
  - <u>Equalizers and Spreader bars</u>: Size and Aspect Ratio Will Affect Load Sharing
  - <u>Block Weight Distribution and Rigidity</u>: Internal Moments







Lifted Dynamic Loads

- What are the Dynamics of a Typical Block Lift?
  - Historical Concern of Lifted Dynamics is Focused on the Effect on the Crane
  - Previous Investigations in the 1940’s and 1970’s Created Data from Incrementing the Crane.
  - Information Collected Pertained to Single Crane Lifts

3. Dynamic Tests on Mill Cranes

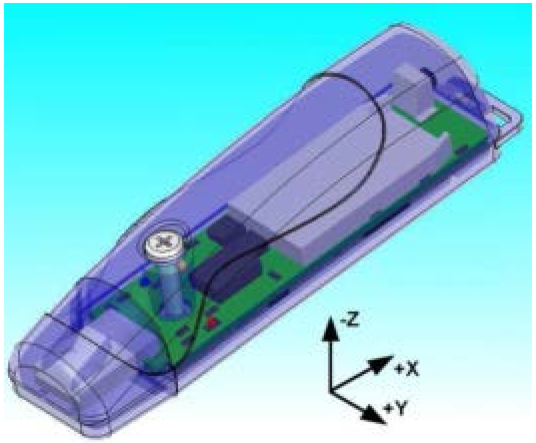
IRON AND STEEL ENGINEER, NOVEMBER, 1941

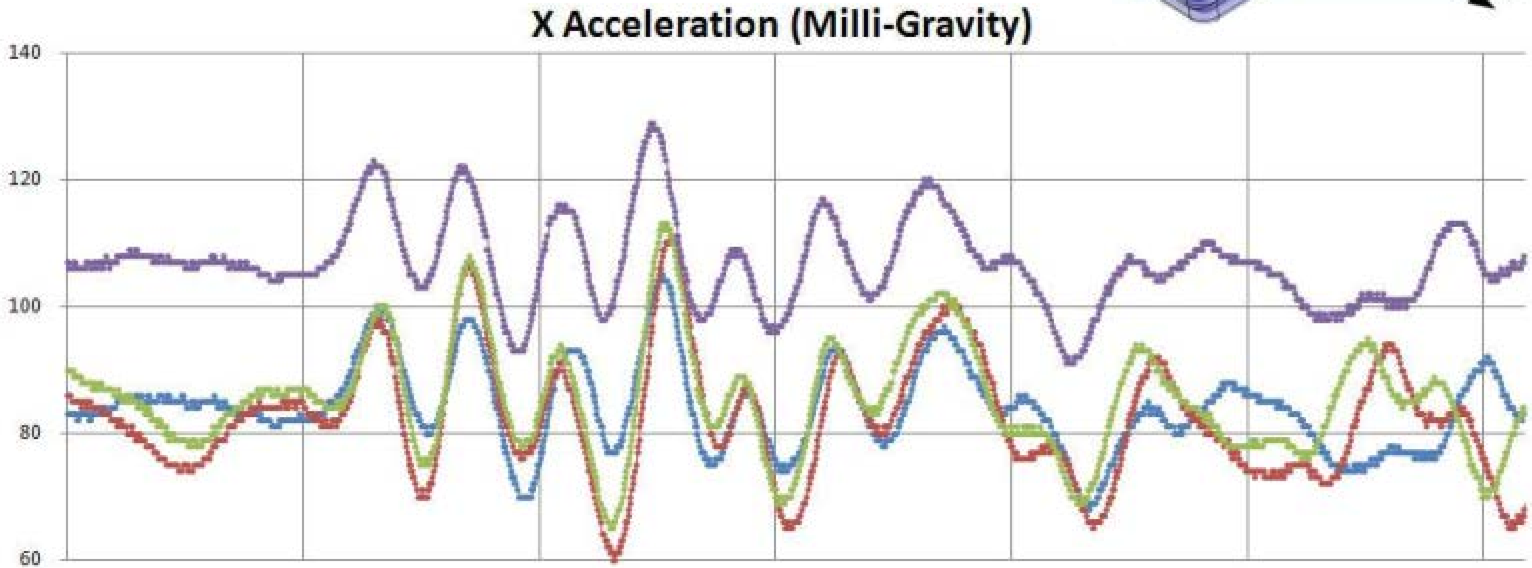
The dynamic stresses in cranes are of two types. One type of dynamic stress is the lateral stress due to acceleration and braking of the crane. This stress may be very large when the crane is of long span and the girders are relatively narrow. The braking stresses are usually larger than the acceleration stresses. The ratio of the braking load to the vertical load on the braked wheels may approach the value of the coefficient of friction between the crane wheel and runway rail. This maximum value may be modified by the timing of the swing of the load on the crane. If the instant of maximum swing should occur with the maximum braking force, the ratio of the maximum lateral force to the vertical force may exceed the coefficient of friction. However, in the tests made, the swing of the pendulum lagged behind the braking force. Lateral forces may also be due to other causes than those above enumerated. One such case would be the use of cranes to spot railroad cars. However, even in such cases, the maximum ratio of lateral load to vertical load should not exceed the coefficient of friction, since at this point the crane would slip on the runway rail.

Lifted Dynamic Loads

- What are Dynamics of Typical Block Lift?
  - Vertical Bouncing: Slings, Crane Boom, Crane, Block
  - Horizontal Swinging: Pendulum From Crane Boom,
  - Complex Motions: Twisting of Rigging, Block Flexing and Twisting

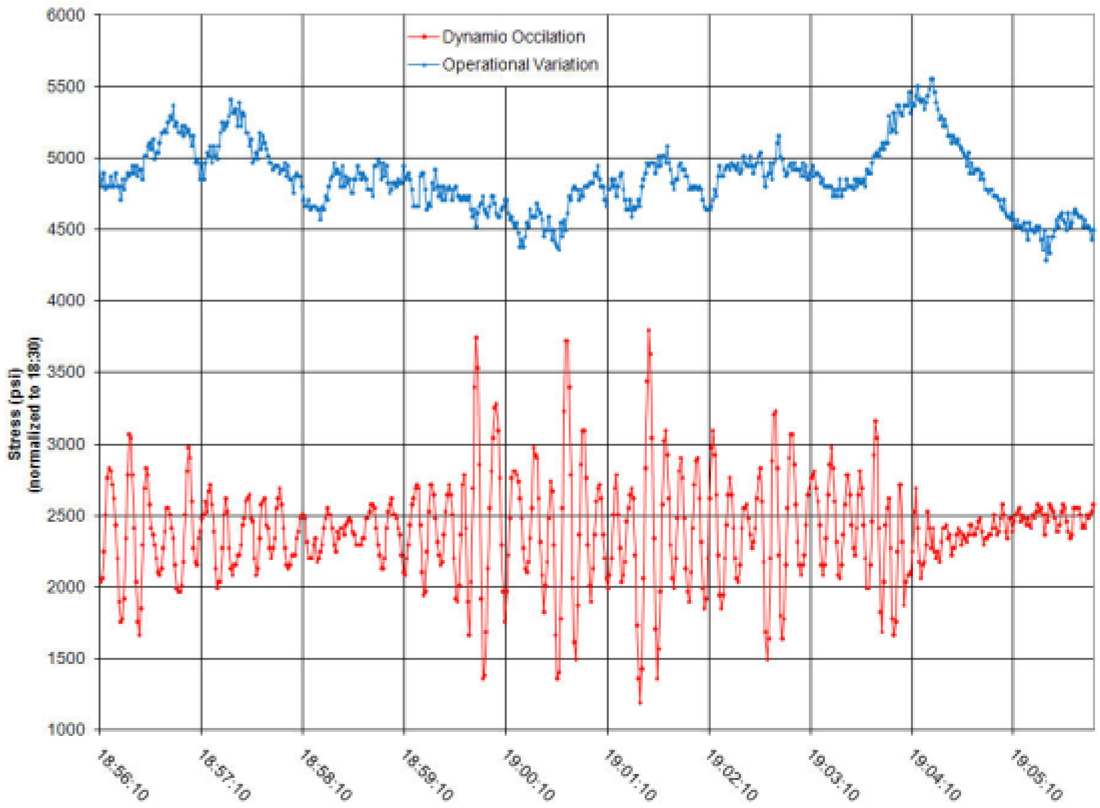
Accelerometer





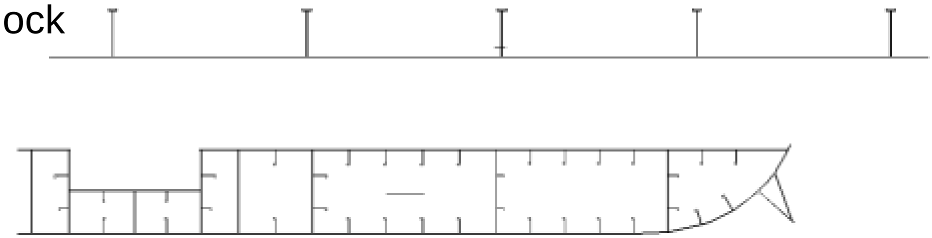
Lifted Variables

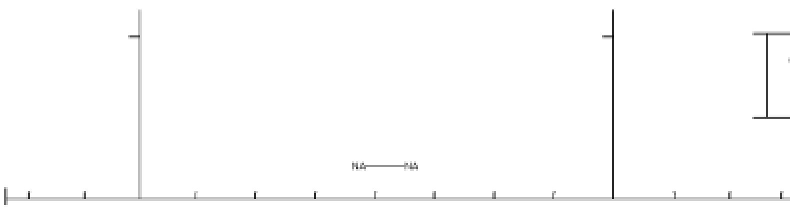
- Measured Stress Patterns Indicated Different Effects
  - Dynamic Loads: Short Period Dynamic Oscillation of Structure
  - Operational Effects: Long Erratic Period, or Variable



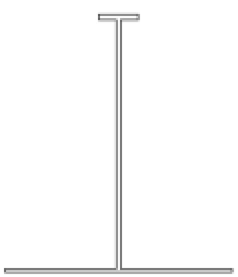
Structural Strength Estimation

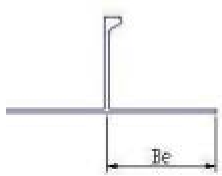
- Classic Strength Estimation Based on Assumed Section
  - Full Block Section Resists Loads Imparted
    - Over Estimates Strength of Block





  - Conservative Minimal Section Estimation
    - Underestimates Strength of Block or Member

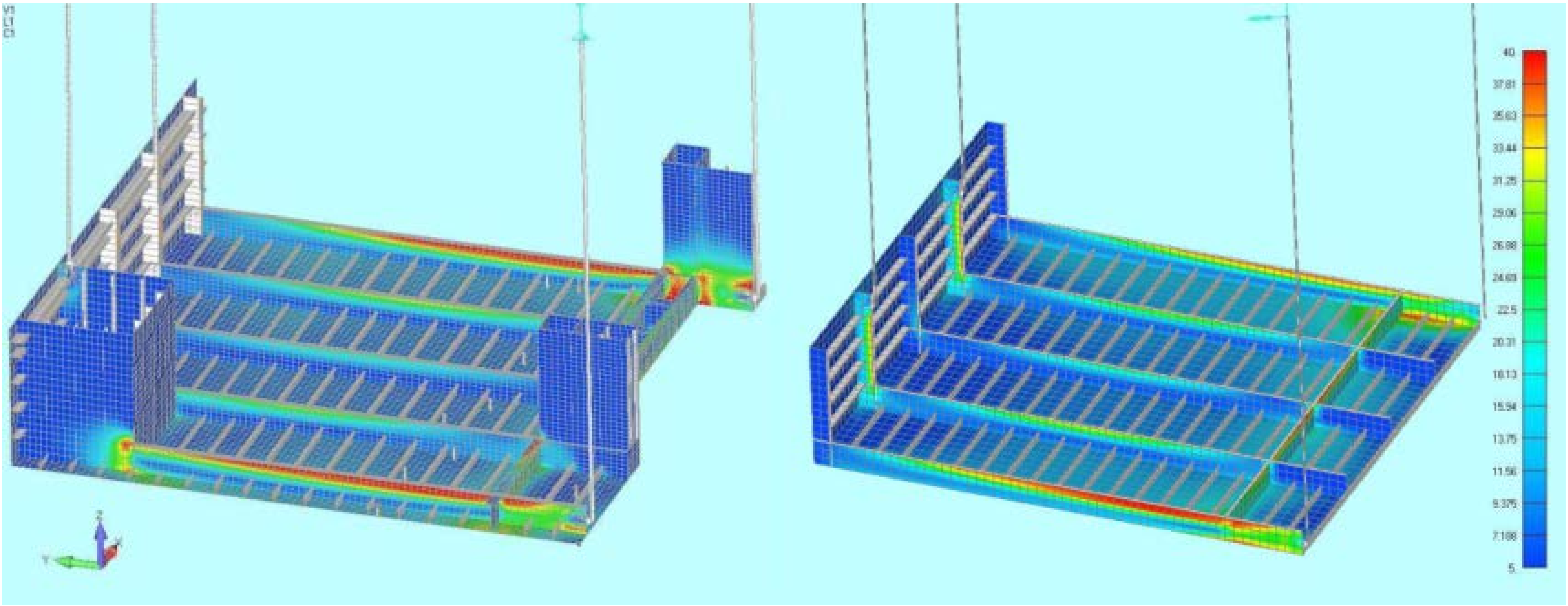




$$b_e = 1.9t\sqrt{\frac{E}{\sigma_y}}$$

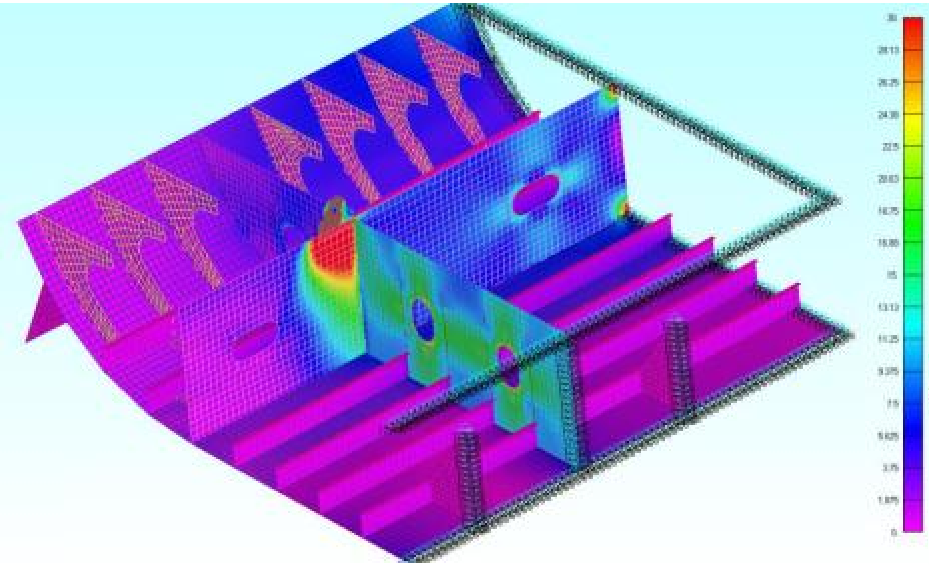
Structural Strength Estimation

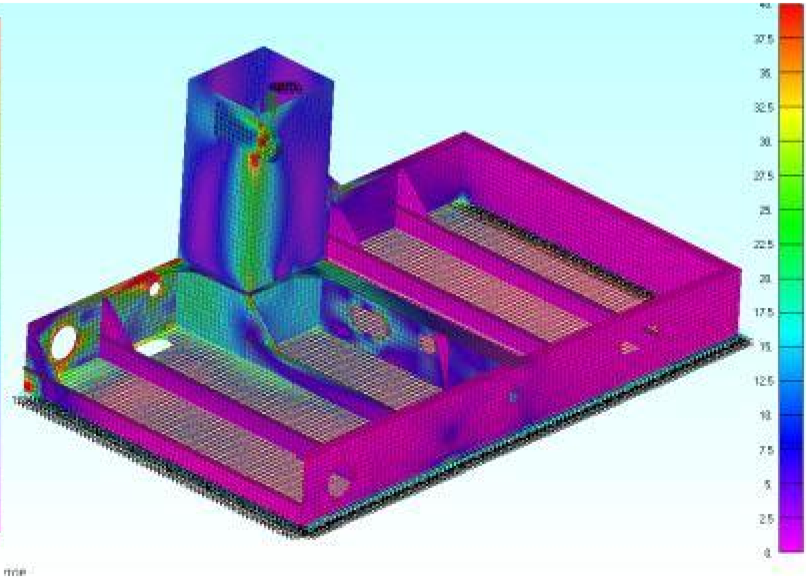
- Linear Finite Element Global Strength Estimation
  - Simplified Structural Model (Right) Time = f(Days)
    - How Many Liberties Can be Taken Without Causing Significant Error (+/-) 30%
  - Detailed Structural Model (Left) Time = f(Weeks)
    - Can This Large Effort be Justified if Operational Variables are (+/-) 50%



Structural Strength Estimation

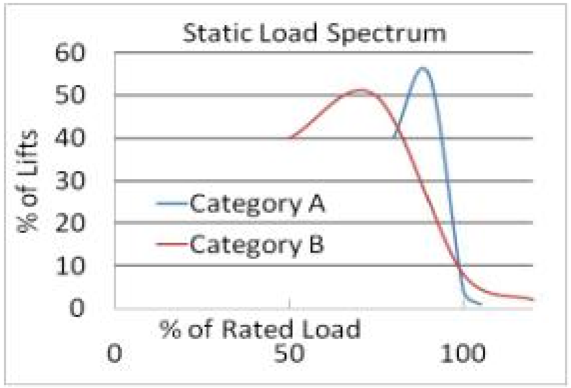
- Local Section Models
  - ➢ Local Models Only Address Local Structure
    - Global Bending Stress is not Always an Issue
    - For a Local Model, How Local is Local
    - Allows the Easy Variation of Sling Force and Angle

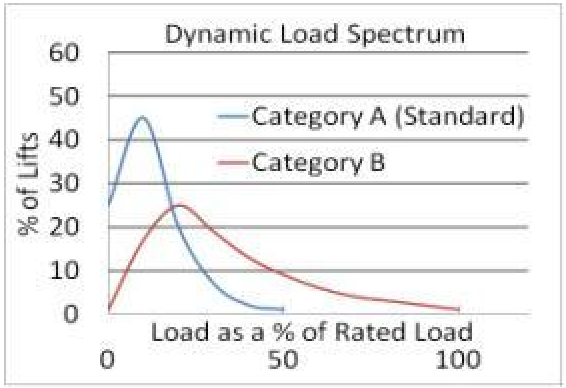




Streamlining Rigging Analysis

- Rigging is a Dynamic and Variable Event
  - What is the Amount of Variation Typically Seen in Shipyards?
    - Weight and COG (Estimate!)
    - Operational Effects (Significant Percentage!)
    - Dynamics Effects(Bouncing, Swinging, Twisting, Side Load on Padeye)
  - Match Structural Estimation of Unit Strength
    - Classic Sectional Analysis (Significant Error Possible!)
    - Linear Finite Element Analysis (Simple, Detailed, Section)
  - ASME Below-The-Hook Bases Design Factor on Probabilistic Loading.
    - Category A is “Engineered”(DF=2) B is Standard(DF =3)





GENERAL DYNAMICS
NASSCO

Current and Future Work

- Four Block Reports Created To Date
- Two More Blocks to be Instrumented and Lifted.
- Two More Block Reports Created.
- Continued Analysis of Data Collected
- Continued Experiments with and Research into FEA Rigging and Modeling Techniques
- Continued Documentation of Operational and Dynamics Effects
- Documentation of Simplified Structural Simplification

Questions?