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Offshore Wind Structure Fatigue Analysis Designed For Coastal New England

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LAME
LASERS AND MATERIALS ENGINEERING

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Increased clean energy needs have spiked interest in harvesting wind energy off the coast of New England. The region experiences drastic changes in weather patterns from season to season, significantly impacting strength, fatigue, and life of offshore structures. In this study, current model offshore wind turbine structures were designed and analyzed to best handle New England's dynamic environmental loads. Three general structure types were designed and analyzed using finite element analysis and ANSYS software. Structures included the four-legged jacket monopile, three-legged jacket monopile, and three-legged twisted jacket monopile. Research validation was performed, proving accuracy of FEA and ANSYS results. Final testing of designs resulted in a best fit structure based on fatigue and strength analysis, maintenance and construction costs, and environmental impacts.

Project Objective

The objective of this project setout to determine the best fit wind energy harvesting structure for New England based on fatigue analysis, cost, and environmental impacts. To do this, three common structures used for offshore wind harvesting were designed using schematics and dimensions. Analysis involved using the finite element method within ANSYS software to determine a structures fatigue life based on research loadings. Validation was performed on a known fatigue study using the software to compare results and the software's accuracy.

Fatigue and Finite Element Analysis Using ANSYS Software

Fatigue analysis studies the formation of cracks within a material under cyclic (fully reversed) loadings leading to failure of a structure or part. Fatigue is measured in a term called Life with units of cycles. Testing is extremely expensive due to destruction of materials/structures and not all materials have fatigue results under cyclic loadings as they have not been experimented with.

Due to the expensive nature of testing, finite element method is used due to its low cost and high reliability of producing accurate results.

Structural Designs Analyzed

- ***Four-Legged Jacket Monopile Design:***
  - (Figure 1) Most expensive structure
- ***Three-Legged Jacket Monopile Design:***
  - (Figure 2) Second most expensive
- ***Three-Legged Twisted Jacket Monopile:***
  - (Figure 3) Least expensive Structure

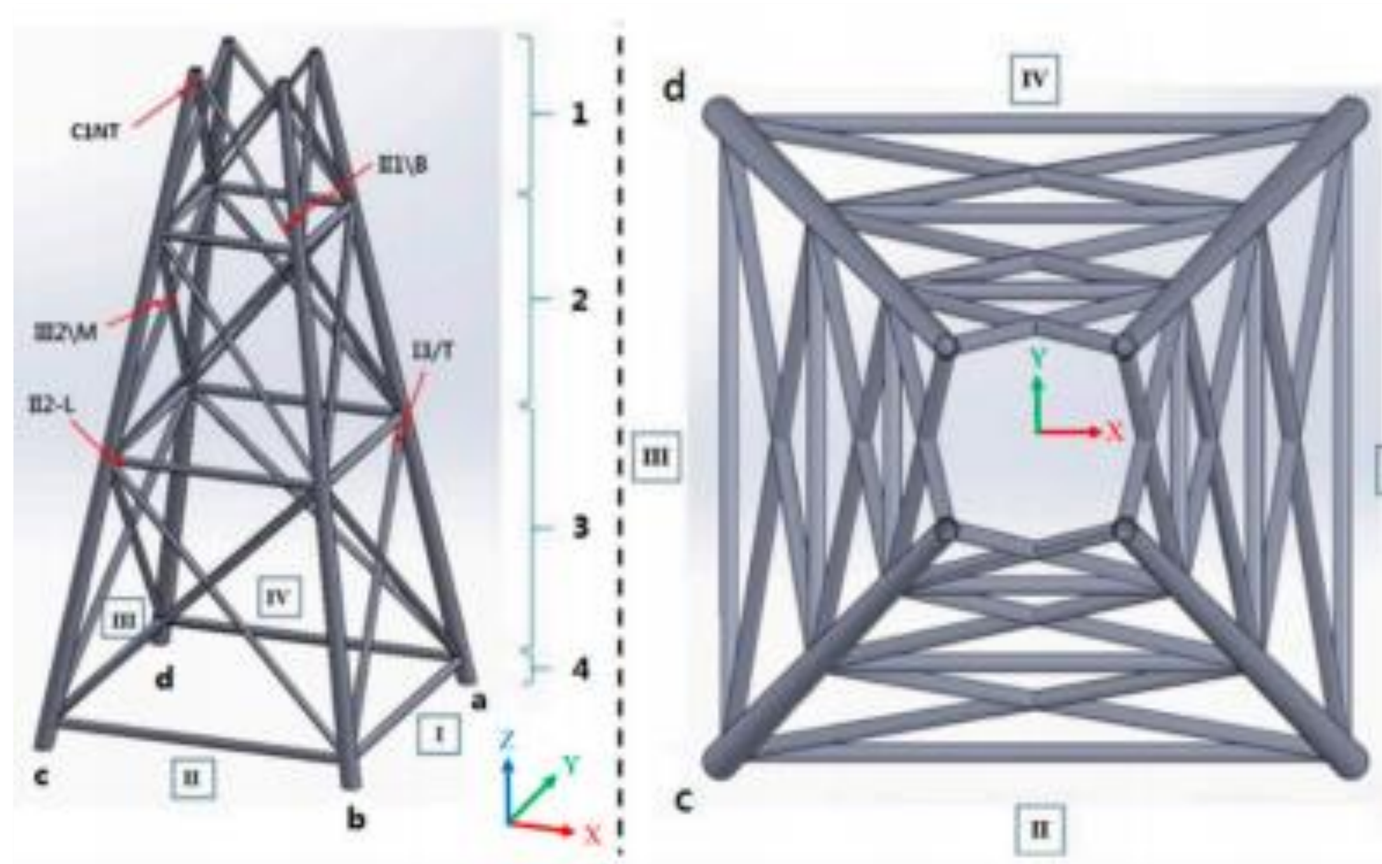
Figure 1. Four-Legged Jacket Monopile Structure Design.

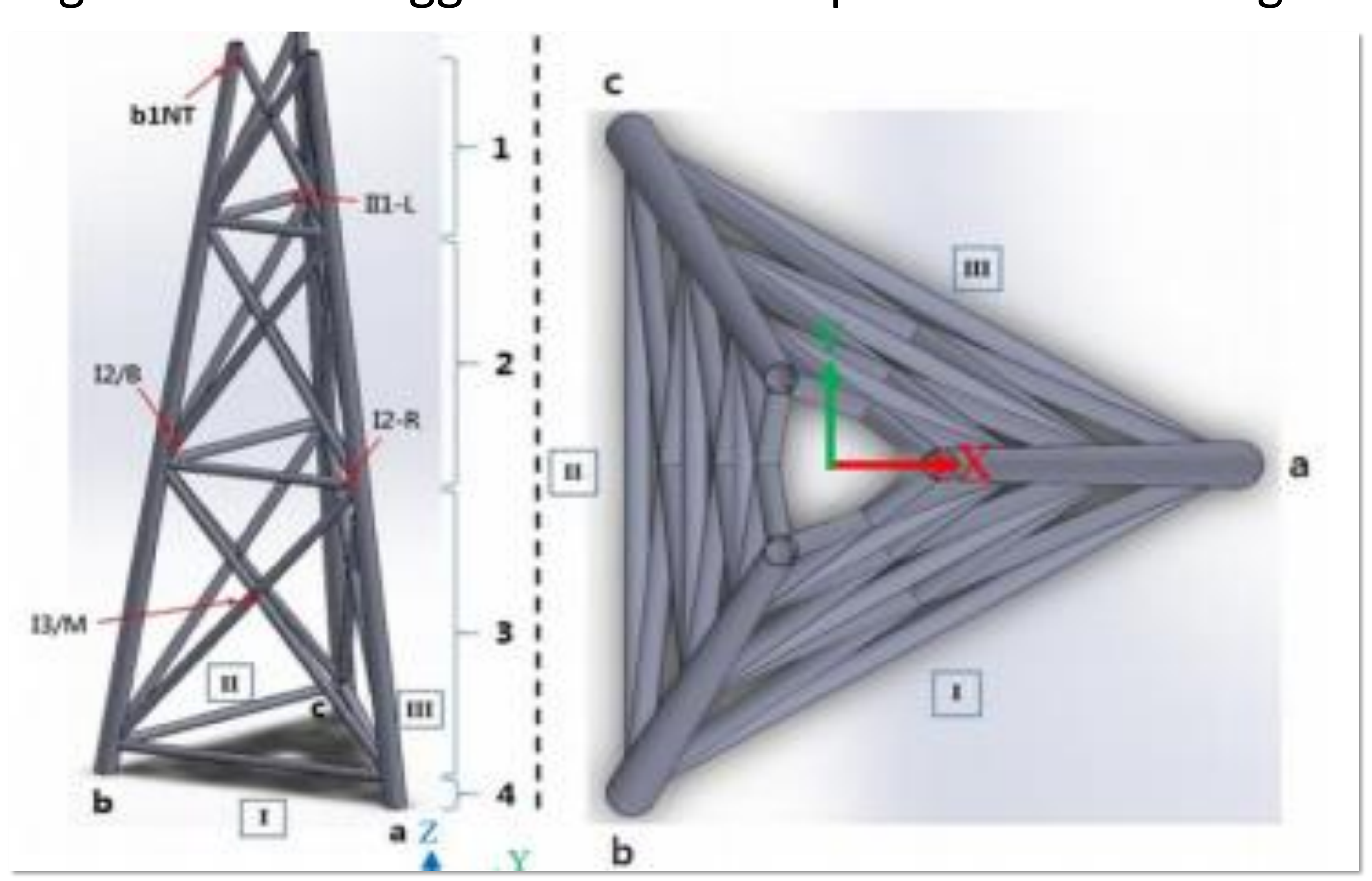
Figure 2. Three-Legged Jacket Monopile Structure

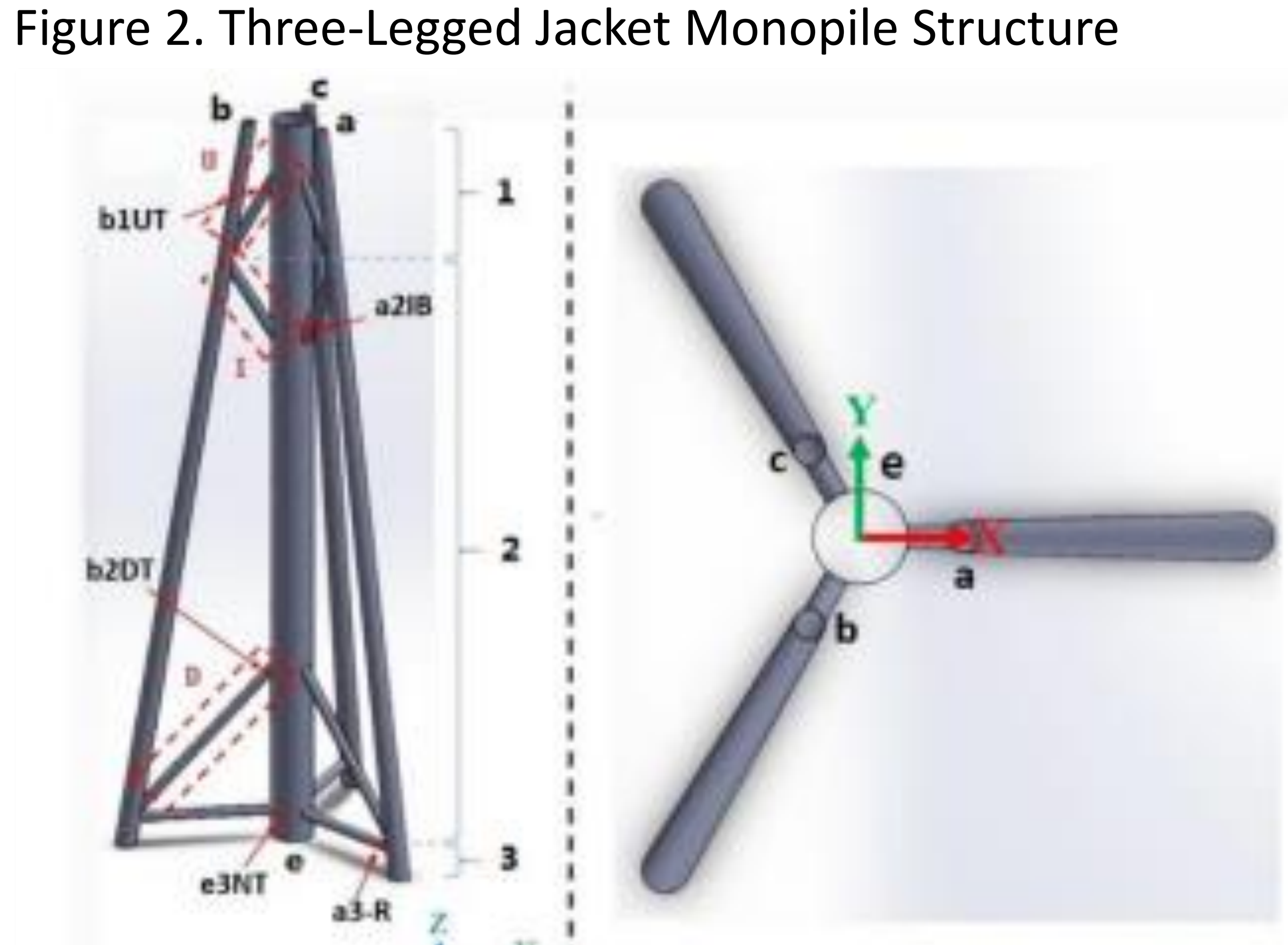
Figure 3. Three-Legged Twisted Jacket Monopile Design.

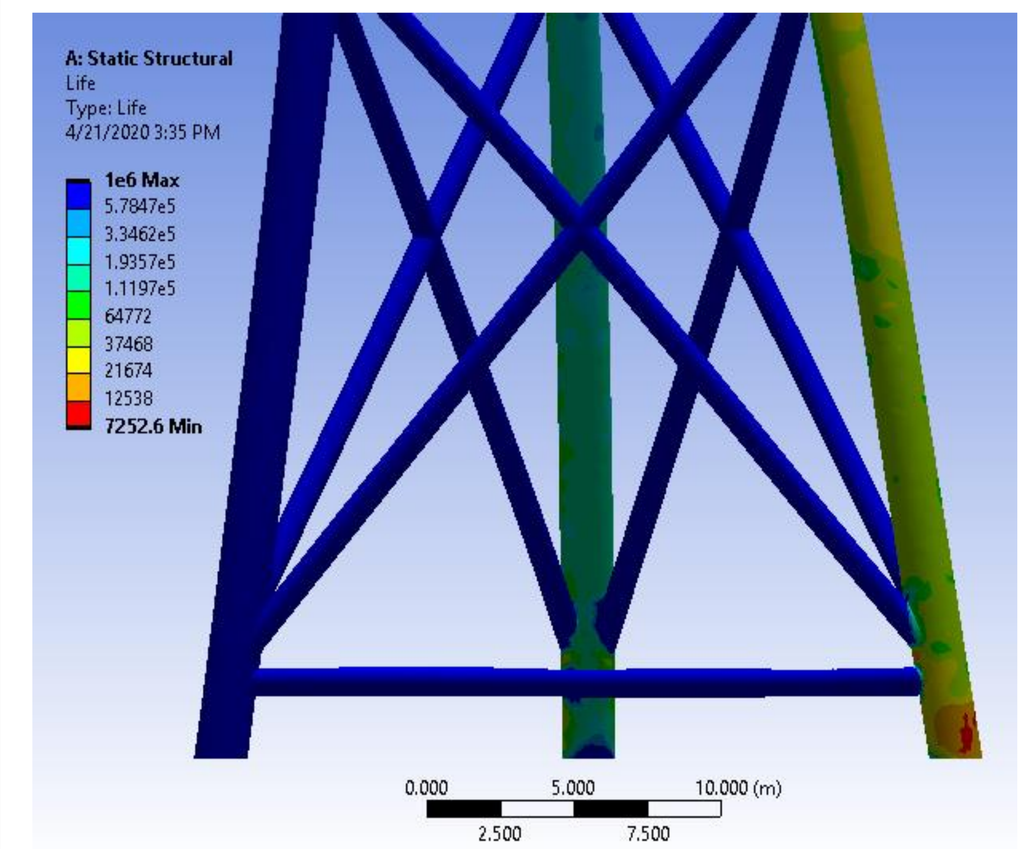

Figure 4. Four-Legged Jacket Monopile Results.

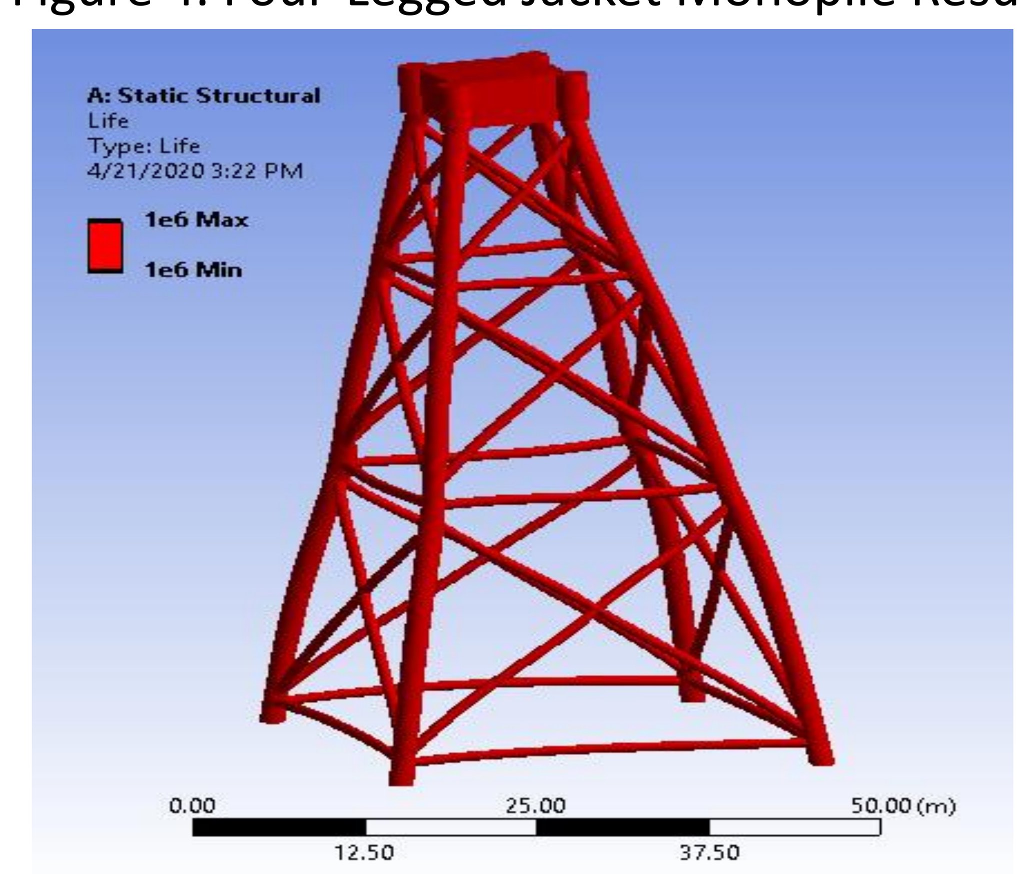

Figure 5. Three-Legged Jacket Monopile Results

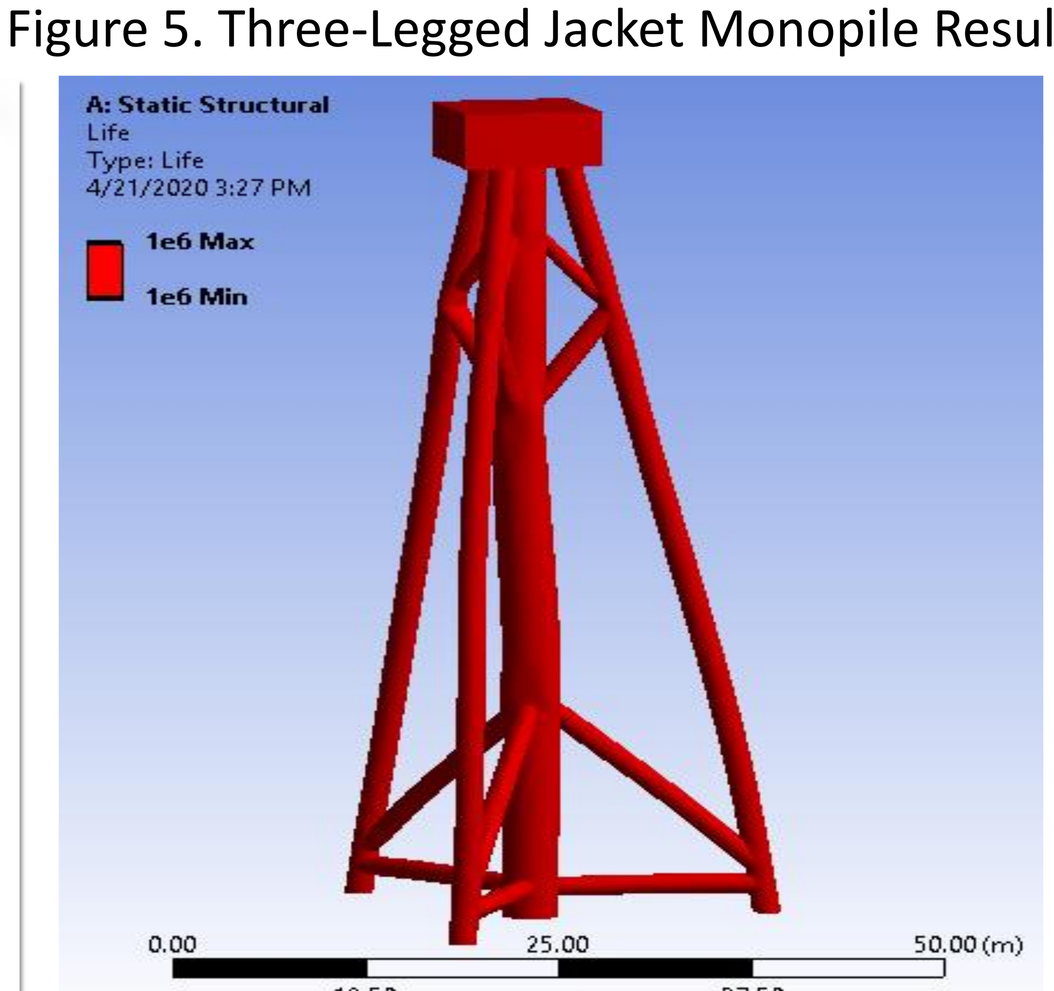

Figure 6. Three-Legged Twisted Monopile Results

Loading Conditions

All three structures were tested under the same extreme loading conditions to determine the best fit model. These loadings included a wind/wave/current split on the structure.

Wave Loading (24m -54m): 4.40 kN

Current Loading (0m – 24m): 404.00 N

Wind Loading (above 54m): 16.44 kN

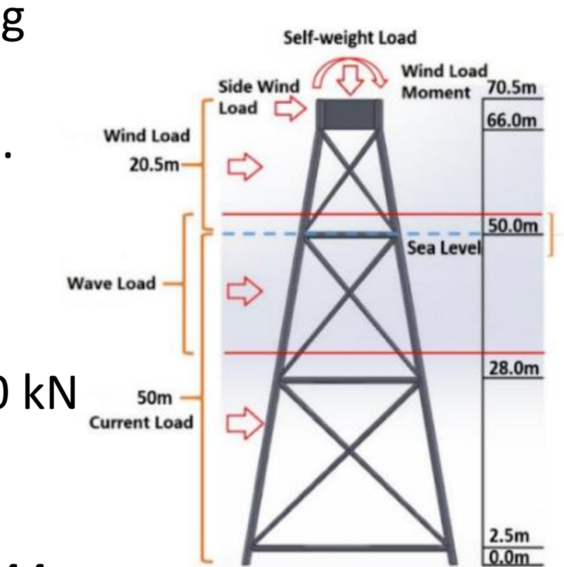

Figure 7. Structural Force Layout

Structural Dimensions/Material

Height: 70.5 meters

Base Width / Length: 24 meters

Material: A36 Steel

Results

The results of the three structures showed the Four-legged jacket structure would begin to fail at 7252.6 cycles at the base of the structure. The Three-legged jacket monopile and the Three-legged Twisted Jacket Monopile both showed no signs of crack propagation after the standard one million cycles under the cyclical testing loads. In theory they would have infinite life without factoring in corrosion, temperature, etc.

Conclusions and Next Steps

The designs resulted in one structure failing and two others that did not. To select from the two cost become the deciding factor leading to the Three Legged Jacket Monopile as the best fit structure for the area. Further testing to be done involves using dynamic loadings, soil testing, and incorporating environmental factors into the analysis.

Acknowledgements:
A big thank you to the USM Lasers and Materials Engineering Research Group

References:
Design and Analysis of Jacket Substructures for Offshore Wind Turbines. I-Wen Chen, et. Al. 2016.